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Forest & Rangeland Ecosystem Science Center
In cooperation with Olympic National Park

Inventory and Monitoring of Amphibians in North Cascades and Olympic National Parks, 1995-1998.

Final Report

Edited by
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EXECUTIVE SUMMARY

Olympic National Park (ONP) comprises 370,000 ha of land on the Olympic Peninsula in Washington State. The park includes the Olympic Mountains as well as a 100-km strip of Pacific coast. ONP has 13 species of amphibians: 3 stream/seep breeders, 7 pond breeders, and 3 terrestrial breeders. Three resident amphibians represent families endemic to the Pacific Northwest. ONP has the richest herpetofauna of the three National Parks in Washington State.

We developed new inventory techniques for amphibians in streams, seeps, and ponds in ONP in 1995. These techniques are suitable and effective for conducting broad inventories when many surveys must be conducted over large areas. The techniques can also be adapted to long-term monitoring and we have developed an example of this approach for streams.

We conducted extensive surveys of streams (167), seeps (250), and ponds (167) in ONP from 1996 to 1998. These surveys determined the distribution and, for streams, abundance of amphibians over most of ONP. We found that most species were common and widespread within the environmental limits that they were previously thought to occur. One exception was the western toad which was rare at high elevations despite its known ability to thrive at high elevations in other regions. The other exception was Cope's giant salamander which was not detected in the northeastern portion of the park including the Elwha River drainage. Reed Glesne and Ronald Holmes simultaneously conducted similar surveys in North Cascades National Park (NOCA; see attached reports).

We assessed the association between amphibians and many environmental variables. Cascade frogs were associated with shallow ponds with high attenuation of ultraviolet-b radiation. This is consistent with a hypothesis that ultraviolet radiation may be contributing to declines in Cascade frogs in other regions. However, we found no evidence that Cascade frogs were declining in ONP. Cascade frogs were less likely to occur when exotic fish (brook trout) were present and long-toed salamanders never co-occurred with exotic fish. Stream amphibians were all associated with the steep climatic gradients in ONP but climate alone did not fully explain the current distribution of Cope's giant salamanders.

Overall, we found few indications of serious amphibian decline in the parks and definitely not of the magnitude that has been documented in other areas such as Colorado and California where toads and ranid frogs have virtually disappeared in many areas. All of the species that were not marginal to the parks to begin with, were relatively common and widespread in our surveys. We have little historic information on the distribution and abundance of these species for comparison so it is possible that some have declined or increased in abundance. However, we see little reason to believe that major changes have occurred.

We have three main concerns: 1) Some pond breeding species (long-toed salamander, Cascade frog) may be reduced or eliminated by introduced fish. This does not appear to be a major management concern in Olympic because these amphibian species are common and widespread in the many fishless ponds that are available, and fish are no longer introduced in ONP. The problem may be more serious in North Cascades. 2) Toads were more rare than we expected in montane ponds of ONP and NOCA. They appear common in some valley bottoms, but this is a species that was historically common at higher elevation in other parts of its range. It is also a species that has declined dramatically in other parts of its range. 3) The absence of Cope's giant salamanders on the northeast side of the ONP is surprising. This species tends to be a habitat generalist compared to the other stream-breeding species and much suitable habitat exists in the northeast corner of the park. Our analysis suggest that this pattern is not entirely a result of the southwest to northeast climate gradient. We recommend that hydrology and potential pollution from the Seattle area be investigated as possible causes.

Both ONP and NOCA are important for long term monitoring. ONP is important because of its environmental gradients and its diverse and unique amphibian assemblage. NOCA is important because it is near the northern extent of the range for several species. We have developed techniques and collected baseline data that will aid future monitoring. These unique characteristics coupled with the amphibian data we have collected provide an opportunity for long-term study of global change and evaluation of declining amphibian hypotheses. We urge continued study and active monitoring of these systems.

Table 1. Amphibians detected by this study in Olympic and North Cascades National Parks, 1995-1998.

Species	ONP	NOCA
Tailed Frog (*Ascaphus truei*)	X	X
Red-Legged Frog (*Rana aurora*)	X	X
Cascade Frog (*Rana cascadae*)	X	X
Columbian Spotted Frog (*Rana luteiventris*)		X
Pacific Treefrog (*Hyla regilla*)	X	X
Western Toad (*Bufo boreas*)	X	X
Long-Toed Salamander (*Ambystoma macrodactylum*)	X	X
Northwestern Salamander (*Ambystoma gracile*)	X	X
Rough-Skinned Newt (*Taricha granulosa*)	X	X
Pacific Giant Salamander (*Dicamptodon tenebrosus*)		X
Cope's Giant Salamander (*Dicamptodon copei*)	X	
Olympic Torrent Salamander (*Rhyacotriton olympicus*)	X	
Western Red-Backed Salamander (*Plethodon vehiculum*)	X	X
Van Dyke's Salamander (*Plethodon vandykei*)	X	
Ensatina (*Ensatina eschscholtzii*)		X

FORWARD

This report is the final product of a four-year project funded by the Natural Resource Protection Program (NRPP) of the National Park Service. It represents the first phase of a planned effort to establish long-term monitoring of amphibians and reptiles in Olympic and North Cascades National Parks. The techniques and baseline data provided here are intended to be incorporated into a larger effort to establish ecosystem monitoring.

Our work to obtain baseline data on amphibian distribution patterns and to develop monitoring techniques is continuing in ONP under the National Park Service's Inventory and Monitoring Program (I&M). At the time of this writing, we consider the stream and seep surveys in ONP to be complete with only minor gaps in the inventory (e.g., upper Queets drainage). This report contains considerable information on pond amphibians, but 1999 surveys funded by the I&M program will provide much additional information and some conclusions may change. Finally, the I&M program will initiate terrestrial amphibian surveys and reptile surveys to round out our coverage of amphibians and reptiles.

Developing monitoring programs involves much interaction with other interested parties and, ultimately, designs must be consistent with access and available funding. We developed a basic monitoring design for stream amphibians using a sampling technique we developed for this project. We will be using data collected here as well as data from the I&M program to develop a monitoring program for pond amphibians. The final implementation of amphibian monitoring will depend on further iteration and integration with the broader goal to establish ecosystem monitoring in ONP. We hope that the NRPP amphibian effort reported here provides a big first step towards that goal.

We focus reporting here on ONP where we concentrated our efforts. Concurrently, we developed a similar sampling program at two other Washington National Parks. We subcontracted studies at North Cascades (NOCA) National Park under the auspices of Reed Glesne and Ronald Holmes (NPS). A parallel effort was directly funded by NRPP via a contract with Gary Larson (USGS) who enlisted assistance from Barbara Samora at Mt. Rainier National Park (MORA).

In 1995, we developed sampling protocols and provided training to all concerned parties (all 3 parks) at a workshop held at ONP. Although we assisted NOCA and MORA in initial design of surveys, some variations in techniques occurred due to local needs. Overall, we report occurrence and abundance of amphibians using similar or comparable methods.

This report focuses on efforts at ONP. Additional reports have been completed for NOCA (Glesne and Holmes 1995, 1996, 1997, 1998). Field surveys continued at MORA in 1999 and a final report will be available shortly. We are discussing options for reporting and publication of results to ensure wide dissemination of this four-year, multi-park effort.

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PRODUCTS

Presentations

1999 Contributed paper. Adams MJ, Bury RB, Schindler DE. Relationship of pond amphibians to attenuation of UV-B radiation in the Pacific Northwest. Annual meeting of the Ecological Society of America. Spokane, Washington.

1999 Contributed paper. Adams MJ, Bury RB. Evaluating amphibian status in Olympic National Park: lack of declines? Annual meeting of the Society for Northwestern Vertebrate Biology. Ashland, Oregon.

1998 Invited paper. Adams MJ. Habitat gradients and the effects of non-endemic fish on amphibians: are there lessons from the lowlands? Workshop on Amphibian-Fisheries Interactions in Wilderness, Flathead Lake Biological Station, Montana.

1998 Invited paper. Bury RB. Fisheries management, amphibians and other biota: what's the problem? Workshop on Amphibian-Fisheries Interactions in Wilderness, Flathead Lake Biological Station, Montana.

1998 Invited paper. Bury RB. Comparison of amphibian trends in the Pacific Northwest. The Wildlife Society, Northwest combined meeting. Spokane, Washington.

1998 Contributed paper. Bury RB, Major DJ. 1998. Declining amphibians in western North America: historical and current perspectives. North American Amphibian Monitoring Program, annual meeting. On-line: http://www.pwrc.usgs.gov

1997 Invited seminar. Bury RB. Amphibian losses in western North America: Facts, fantasies, and research needs. College of Forest Resources, University of Washington, Seattle.

1997 Invited presentation. Bury RB. Sampling designs for aquatic and streamside amphibians and their habitat. Meeting, Riparian Ecosystem Management on Olympic Peninsula. US Forest Service and private industry. Olympia, Washington.

1996 Invited paper. Bury RB, Major DJ. Inventory and sampling designs for surveys. Workshop on Declining and Sensitive Amphibians, Boise, Idaho.

1996 Plenary address. Bury RB. Amphibian conservation in western North America: progress, pitfalls and perspectives. IUCN/SSC Declining Amphibian Population Task Force – Canada. Calgary, Canada.

1996 Contributed paper. Major DJ, Bury RB. Integrative sampling: an adaptive inventory technique for pond-breeding amphibians. IUCN/SSC Declining Amphibian Population Task Force – Canada. Calgary, Canada.

1995 Invited paper. Bury RB, Dodd K. Status and changes in North American Amphibians. Annual meeting of The Wildlife Society. Portland, Oregon.

1995 Invited paper. Bury RB. Inventories and sampling designs for surveys: overview. Conference on declining and sensitive amphibians, USFWS, BLM, USGS, and others. Boise, Idaho.

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Completed

2001 Adams MJ, Schindler DE, Bury RB. Association of amphibians with attenuation of ultraviolet-b radiation in montane ponds. Oecologia *in press*.

2000 Adams MJ, Bury RB. Amphibians of Olympic National Park. USGS Fact Sheet. FS-098-00. 4pp.

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1999 Bury RB, Adams MJ. Variation in age at metamorphosis across a latitudinal gradient for the tailed frog, *Ascaphus truei*. Herpetologica 55:283-290.

1997 Adams MJ, Richter KO, Leonard WP. Surveying and monitoring pond-breeding amphibians using aquatic funnel traps. In: Olson D, Leonard W, Bury R, editors. Sampling Amphibians in Lentic Habitats: Methods and Approaches for the Pacific Northwest. Northwest Fauna 4:47-54.

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1997 Olson DH, Leonard WP, Bury RB, editors. Sampling amphibians in lentic habitats: methods and approaches for the Pacific Northwest. Olympia, Washington, USA: Society for Northwestern Vertebrate Biology. 134 p.

Submitted

Adams MJ, Bury RB. Endemic headwater stream amphibians of the Pacific Northwest: associations with environmental gradients in a large forested preserve. Submitted to *Global Ecology and Biogeography* (Oct 2000). 26 pp.

Bury RB, Loafman P, Rofkar D, Loafman K. Nesting ecology of tailed frogs (*Ascaphus truei*) in coastal Washington. Submitted to *Northwest Science* (Nov 2000). 15 pp.

Manuscripts In Progress

Pearl CA, Bury RB, Adams MJ. Status of Cascade frogs in the Pacific Northwest: a critical review.

Bury RB, Adams MJ, Pearl CA, Major DJ. Occurrence and status of amphibians in National Parks of Washington State: a region lacking declines.

Major DJ, Bury RB. Amphibian surveys for headwater streams using random selection of sampling belts.

Bury RB, Major DM. Habitat use of seeps by amphibians in Olympic National Park.

Archived Data

‘ONP Pond Amphibians 96-98.mbd’ Microsoft Access 97 database. 324 KB. 5/17/2000.
NBII compliant metadata for ‘ONP Pond Amphibians 96-98.mbd’.
‘ONP Seep Amphibians 96-98.mbd’ Microsoft Access 97 database. 236 KB. 8/2/2000.
NBII compliant metadata for ‘ONP Seep Amphibians 96-98.mbd’.
‘ONP Stream Amphibians 96-98.mbd’ Microsoft Access 97 database. 812 KB. 5/17/2000.
NBII compliant metadata for ‘ONP Stream Amphibians 96-98.mbd’.

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INTRODUCTION

As the magnitude of global declines in biodiversity becomes more apparent, increasing emphasis is being placed on documenting species occurrence patterns and developing suitable means for monitoring and assessing threats to biodiversity. Traditionally, population size has been a focus of monitoring, but is difficult to measure and is unrealistic for examining broad patterns involving multiple species. Various indices of abundance can sometimes be substituted for individual species, but the relationship between such measures and true abundance is difficult to establish and, once again, this approach can become daunting for large areas and multiple species.

Efficient methods are needed to periodically sample amphibian populations in a manner suitable for inferring trends in the desired response variables. The range of inference may be a habitat or a region and the response variable may be the relative abundance or occurrence of a specific species, species richness, or a community matrix. The difficulty of developing such methods is evidenced by the lack of suitable protocols and historic data.

The U.S. National Park Service is charged with preserving examples of the native biota. It has become increasingly clear that setting aside land in reserves does not insure the preservation of the resident species. Global effects such as climate change and air-born pollutants can impact species as well as more localized effects from habitat fragmentation, exotic species, and recreation. Such threats necessitate that the biota of the National Park system be inventoried and monitored and financial constraints necessitate that the methods for doing so be highly efficient.

Olympic National Park (ONP) comprises 370,000 ha of land on the Olympic Peninsula in Washington State. The park includes the Olympic Mountains as well as a 100-km strip of Pacific coast. Elevations range from zero to over 2000 meters. The Olympic Mountains are isolated from other mountain ranges in the region and are characterized by glaciated peaks and steep elevational gradients. ONP is almost entirely roadless and trails are mostly confined to valley bottoms and some steep ascents up to ridges and glacial basins. Off of established trails, access to the steep terrain is difficult, potentially dangerous, and time intensive. High elevations are alpine meadow, rock, and glacier; most of the rest of the park is old-growth forest.

ONP has 13 species of amphibians: 3 stream/seep breeders, 7 pond breeders, and 3 terrestrial breeders (Nussbaum et al. 1983). One of these, the Olympic torrent salamander is endemic to the Olympic Peninsula (Good and Wake 1992). Five other species in ONP are roughly endemic to the Pacific Northwest: Cope’s giant salamander, Van Dyke’s salamander, tailed frog, Cascade frog, and western red-backed salamander. Three resident amphibians (tailed frogs, Olympic torrent salamanders, and Cope’s giant salamanders) represent families endemic to the Pacific Northwest. There are also six species of reptile (three of which are garter snakes) on the Olympic Peninsula, but only 3 are known to occur in ONP (common garter snake, northwestern garter snake, rubber boa). ONP has the richest herpetofauna of the three National Parks in Washington.

This report describes a four year effort to describe amphibian distribution patterns in Olympic and North Cascades National Parks. The emphasis of this work was to conduct a basic inventory of stream and pond breeding amphibians. Doing this required the development of new sampling techniques suitable for covering a large area and for replication at a later date. We also examined habitat relationships and, to a lesser extent, studied natural history patterns and developed long-term monitoring protocols.

SURVEY TECHNIQUES

Amphibian Survey Protocol for Headwater Streams

R. Bruce Bury and Donald J. Major

Overview

This protocol was designed to examine species richness and relative abundance of amphibians in permanent headwater stream systems. Permanent headwater systems are defined as 1st or 2nd order streams with continuous surface flow. The stream must have an average wetted width of ≤ 5-m at the lowest portion of the hydroperiod (i.e., mid to late summer).

This is a new sampling scheme for streams that randomly selects 10 stream meters per 100-m of stream. Amphibian surveys are conducted in a 1-m wide "belt" transect placed perpendicular to the main channel at each of the 10 sites (Figure 1). Although area surveyed (m^2) will depend on the wetted width of the stream, all surveys will examine ~10% of the available area within the 100 m section of stream. We call this the "10% Rule". Also, by incorporating randomized sampling, predominant habitats should be sampled proportional to their availability.

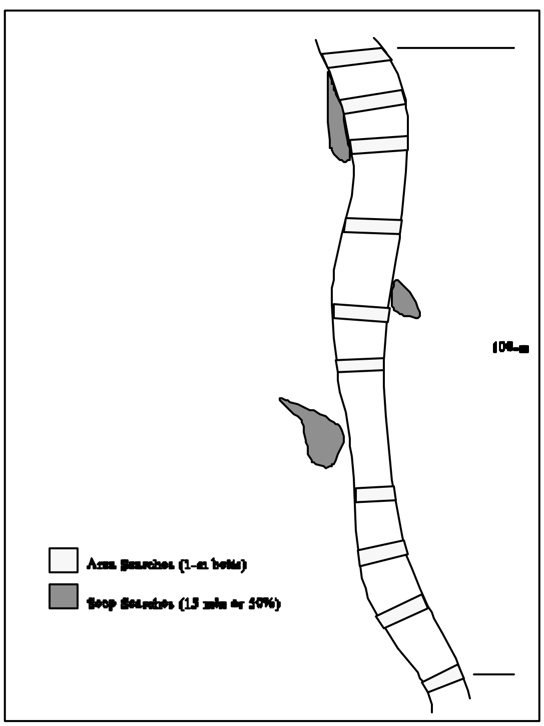

Figure 1. Schematic of random-10 headwater survey design.

Justification and Background

This method builds on prior sampling methods for stream amphibians. Bury and Corn (1991) employed one 10-m long belt per stream. Welsh et. al. (1997) uses a stratified random design which surveys 0.6-m belts in proportion to numbers of habitats. It required a habitat survey prior to the amphibian survey. Bury and Major (unpublished data) used three 5-m long belts equally placed within a 100-m section of stream. These methods offer standardized and repeatable surveys. However, we propose a system with random selection of belts in stream sampling.

Methodology

Many of the stream measurements and sampling are in Bury and Corn (1991). The new survey will be conducted in 4 stages:

Stage 1: Stream Segment Establishment

Search along all trails and roads in a drainages for permanent streams in the fall prior to each years surveys. Record the location of suitable streams by pacing the distance to them along the trial from obvious landmarks or using a global positioning system. This will define the population of streams for which the surveys provide inference. In this manner, surveys will not be limited to mapped streams and will include permanent waters. At ONP, we randomly selected half of the identified streams in each drainage for sampling.

For each randomly chosen stream, establish a start point 30-m upstream from the trail, then randomly chose 10 1-m belts out of the next 100 possible belts. Surveys will occur at these belts.

Stage 2: Characterization of Physical Features

Prior to surveying each 1-m belt for amphibians, measure stream morphology and general habitat characteristics. Definitions are included in Table 2.

Stream Morphology

A 1-m long marker stick in combination with pin-flags was used to delineate the 1-m belt. Stream width (wetted) was measured at the downstream edge of each 1-m belt. Water depth was measured at the downstream edge of each 1-m belt and recorded as the average of three measurements taken equi-distance across the wetted width (Figure 1). Gradient was recorded at 0, 50, and 100-m using a clinometer and fixed height stakes. Gradient measurements were taken from the thalweg (the lowest point in the stream channel).

General Habitat Characteristics

Substrate was visually estimated and recorded at the downstream edge of each 1-m belt using a 0.1 x 0.3 m view box. We constructed view boxes by cutting a rectangle out of the bottom of a plastic "shoe" box and then gluing a piece of plastic glass in the hole (secured with bolts). Substrate is classified into 2 categories (Dominant and SubDominant) based on substrate size (Platts 1983). Habitat was recorded over the entire area of each belt. Flow was visually categorized as percent 'Fast' flowing (i.e., riffle) and 'Slow' flowing (i.e., pool). Climatological data will be taken 1-m downstream of the starting point for the stream segment. If multiple days are required to complete the survey, we recorded climate data for each day.

Stage 3: Amphibian Sampling

Prior to the survey, visually scan the belt area for animals. Small streams (<1.5-m wide) require a single surveyor to conduct the search (and one person to record). Survey larger streams ($\geq$1.5-m) using 2 people and start from the center of the stream and work towards the edges. Limit stream amphibian searches to the loose surface layer of substrate on the stream bed and all objects in contact with the wetted edge of the stream (i.e., use a 'light touch'). Pick-up and replacement of objects is preferred. To increase detection of animals, we recommend the use of a viewbox (0.1 x 0.3-m) in combination with wire screens or dip-nets with a D-shaped rim. No boulders, rocks, or large woody debris that are embedded or wedged tightly are to be moved. However, run hand along surfaces as this can dislodge or flush animals. Captured animals are placed in water filled bags, measured, and released at capture point.

Stage 4: Seep Surveys

Besides stream surveys, we conduct surveys of seeps, springs, or rivulets encountered both along the stream and within the riparian area along either side of the 100-m survey unit. Survey these areas with the same 'light touch' defined above. Survey these sites using the 50/15 rule: 50% of the area *or* 15-minutes per site, whichever occurs first.

Exceptions

If the randomly selected sample point is deemed unsafe by surveyors, then select another random number. Otherwise, stick with the original random numbers or adjust belt position as in the following scenarios:

*Large log across stream- Survey immediately below log.

*Waterfall- Survey at base of waterfall if enough horizontal area.

*Deep plunge pool- Survey shallows (<0.5-m deep).

Table 2. Definition of stream sampling variables.

Location Information

SITE NAME - A name that has some relation to the site being surveyed, such as the name of the stream.
SITE NUMBER - This will be provided by the computer when data is entered.
DATE - dd/mm/yy
T - Township determined from map.
R - Range
S - Section
1/4 - 1/4 Section
1/16 - 1/16 Section
WEATHER - Code:

Cloud cover	Precipitation	Wind
CL=Clear	D=Dry	C=Calm
PC=Partly Cloudy	F=Fog	LB=Lt Breeze
CO=Cloudy/Overcast	M=Mist	MB=Moderate Breeze
	LR=Lt Rain	W=Windy
	HR=Heavy Rain	G=Gusting
	SL=Sleet	
	SN=Snow	

AIR TEMP - Should be taken at least 1 meter above the stream. Use degrees Celsius, unless only a Fahrenheit thermometer is available. Circle C or F depending upon scale used.
WATER TEMP - Temperature of the water within the stream. Use degrees Celsius, unless only a Fahrenheit thermometer is available. Circle C or F depending upon scale used.
UTM-N and UTM-E - determined as accurately as possible from topographic map.
SURVEYORS - Record the first, middle, and last initial of those people actually doing the survey.
RECORDER - Record the name of the person that is recording the data. If a recorder is also a surveyor, place their initials in both places.
ASPECT - General direction that the survey site (at stream meter 0) and surrounding area is facing (e.g., N,NE,E,SE,S,SW,W,NW).
GRADIENT - Measure of slope taken at stream meter 0, 50, & 100-m of stream survey. Recorded as a percent (0-90%)
PHOTO TAKEN - Indicate whether a photo was taken for the region being surveyed.
STREAM M - Indicate the stream meter at which the photo was taken.
ROLL # - Indicate the film roll that the picture is on.
PICTURE # - Indicate the picture number for the roll that you are using.

Stream Measurements

STREAM METER - "0" is used to indicate the stream meter where the survey starts. If multiple plots are done within a survey, then each plot is identified by the stream meter at the downstream end of the plot.
WIDTH - The average width of the plot being surveyed, from wetted edge to wetted edge. Measurements should be recorded in cm.
DEPTH - Measured in cm while facing upstream.
"L" measured halfway between center and left bank
"M" measured in the center of the stream
"R" measured halfway between center and right bank.
FLOW - Looking over the entire belt. Indicate percent of water that is fast flowing (e.g. riffle) and percent that is slow flowing (e.g. pool). Percents should add up to 100.
SUBSTRATE - See Capture Data Form for Substrate categories. Measurements will be taken from visual categorization of the Dominant and Sub-Dominant substrate occurring on each 0.3-m line segment as you move across the stream (Left to right - facing upstream)
Dom = the dominant substrate across the entire transect
Dcnt = total number of times Dom (from above)was observed
Sdom = the next dominant substrate after Dom across the entire transect
Scnt = total number of times Sdom (from above) was observed
Total = total number of 0.3-m line segments across the stream
INST COVER % - LWD = Large Woody Debris (>5-cm diameter)
OD = Organic Debris (other than wood, ex. leaf litter)
UB = Undercut Bank.
For the plot being surveyed indicate the percent of the plot that is covered by each type of cover.
OVER ST % COV - Percent of the stream that is shaded by vegetation.
COMMENTS - General comments/notes pertaining to the specific survey (e.g., deviations from protocol, problems encountered, etc) and/or general departures from the 'norm'.

Map and Capture Summary

METHOD - Indicate the type of survey method being used (i.e. 10 random 1m w/in 100m, 10m Bury/Corn).
START - Time when you start surveying the plot. This does not include time for measurements, or map drawing.
END - Time when you finish surveying the plot. This does not include time for measurements or map drawing.
MAP - Before the start of the survey, draw a basic outline of the plot. Identify major aspects of the section (i.e. large boulders, downed logs, pools). On the left side of the map indicate the stream meters at which the plot starts and ends and give an approximate scale of width across the bottom.
CAPTURES SUMMARY - At the end of the survey, summarize the species captured, their stage and sex (if possible) and the number captured.

Sampling Pond Amphibian Communities In Montane Habitats[1]

R. Bruce Bury and Donald J. Major

Introduction

There is a clear need for regional or national inventories, tested and reliable sampling methods, and standardized protocols for pond-breeding amphibians (Corn and Bury 1989; Heyer et al. 1994b; Green 1997). However, amphibian sampling generally requires a trade-off between rigorous statistical design (often with labor-intensive methods that are able to assess only a few populations) and techniques that can be employed over wider landscapes (i.e., increased coverage better measures variation in aquatic ecosystems). Also, standardized techniques are necessary to determine animal occurrence and abundance for *inventories* that are generally visits to many sites in one time period (e.g., one summer) or *monitoring* that usually embraces attempts to detect changes in population parameters over time.

Specifically, we needed to inventory and monitor amphibians in montane lakes, ponds, and wetlands in National Parks of the Pacific Northwest. These parks encompass large geographic areas with highly varied habitats and great elevational changes over short distances. Information on amphibians is essential because there is a mandate to protect all wildlife within these parks. Thus, there was high biological and management interest to *inventory* the current distribution of amphibian populations (e.g., this sampling protocol) and, in subsequent years, to implement a *monitoring* program to determine trends with repeated surveys at selected sites.

Although our goal was to develop an effective sampling design for montane waters within the Pacific Northwest, the design should be applicable to other regions (see Olson and Leonard 1997). In Olympic National Park, we needed to sample many sites in montane areas, waters with a variety of habitats, and where there was access to most of the shoreline. The design may be adapted to lowland situations without shrubs or other vegetation blocking access around the shoreline. In heavily vegetated waters, funnel trapping alone is the preferred option (Adams et al. 1997).

Our objectives were to: (1) design a sampling regime based on random selection of study sites; (2) evaluate criteria for selection of sites and sampling techniques; and (3) develop a methodology to inventory the species richness (number of species present) and occurrence patterns of aquatic amphibians. This chapter provides a step-by-step description of the design and sampling techniques to inventory amphibians.

Integrated Sampling Protocol

Because specific questions and objectives of each study drive the sampling design and scope of projects, it is useful to have a "tool box" available with alternative methods and techniques. Small waters (e.g., ponds) are entirely surveyed by what is called a ‘Basic Survey’ (Thoms et al. 1997), which is a visual search around a pond’s perimeter and shallows. Larger waters require more effort (person-hrs) because of their size but actually have proportionately less coverage (e.g., the deeper parts are not surveyed).

We present an integrated sampling protocol that requires more effort than ‘Basic Surveys’ but is less time-consuming than intensive, habitat-based searches (e.g., Crisafulli 1997). Although serving as an option between these two approaches, we also offer the protocol as an effective sampling tool to inventory amphibians over large landscapes. Further, this new protocol is (1) adaptable because it encompasses the range of sizes among sites and the varied types of aquatic habitats within sites, and (2) integrative because we employ several techniques to sample amphibians.

The sampling design is based on several sources. First, we re-examined the approaches and standardized data forms prepared in earlier methodologies on amphibians in western North America: (1) terrestrial (Corn and Bury 1990), (2) stream (Bury and Corn 1991), and (3) ponds (Corn et al. 1989). These were considered with recent advances in techniques (Heyer et al. 1994a; Fellers and Freel 1995; Green 1997). Then,

[1] This paper was previously published in *Northwest Fauna* 4, a publication of the *Society for Northwestern Vertebrate Biology*.

we developed a working draft and field-tested the sampling design in the summer of 1996. Here, we attempt to incorporate these innovations into one system for pond-breeding amphibians. Much of our design is included in a recent publication (Bury and Major 1997).

We define relative abundance as how many individuals of each species were observed or caught per unit time. It is not a population estimate, which requires rigorous studies repeated over time to be valid (e.g., mark-and-recapture techniques). The new protocol should reveal regional distributions and occurrence patterns of pond-breeding amphibians (Presence/Not Found). We suggest avoidance of the term '*absence*' as it is difficult to prove species are absent, particularly amphibians which tend to be cryptic, nocturnal and seasonally abundant (Fellers 1997).

Site Selection

Identification of Study Sites

We use USGS 7.5' Topographic and National Wetlands Inventory maps to locate water bodies. A Geographic Information System helped identify these waters in Olympic National Park, our primary study area. Within each basin, we plot increasing zones around the periphery of each identified water body, which creates polygons and then patterns of lake distribution (isolated waters or clusters). For polygons (clusters) with 4 or more sites, we randomly select 50% within each polygon for surveys. All waters are surveyed in polygons with $\leq$3 sites.

As an example, we found 57 mapped waters in a cluster located in the Seven Lakes Basin of Olympic National Park, which were all in the Sol Duc River drainage. We randomly selected 50% (n=28) of the sites within this cluster for surveys. One adjacent lake in the Bogacheil River basin was relatively close to the Sol Duc cluster. We surveyed it as an additional site.

Random Site Selection

Integrated sampling can be used with complete, representative or random sampling of study sites (Fellers 1997). The large size and remoteness of the National Parks precluded complete surveys. Representative sampling was not used as we would need to first determine the range and distribution of all waters. Also, preliminary analyses revealed great variability in size and type of waters across basins, in part related to marked topographic relief and different glacial histories. Purely random site selection would require arduous and unsafe work. In a few cases, sites are not accessible or rarely available (e.g., melt pools below glaciers that can be reached only during a few weeks in the summer).

We decided to use a stratified random process because of the large area needing surveys within each National Park and funding restrictions. Our sampling did not cover the full range of habitats available because of the isolation and remoteness of some sites. Rather, sampling sites were reasonably accessible from roads or trails: within moderate (2 km) hiking distances. Much of the survey work is still in back country or wilderness areas.

We randomly selected 50% of identified and accessible waters within each basin, which proved to be the most efficient way for us to sample all basins in the parks with the time (summer access only to most basins) and funding available. Stratified random selection of sites within each basin maintains a degree of statistical rigor in sampling that is lacking in many other studies. Return visits to sites will be enhanced because they are reachable within a few hours hike of existing roads or trails. This is an important consideration for future monitoring efforts that require repeated visits during varied periods of seasonal activity by amphibians.

Survey Design

Survey Techniques

Daytime Searches

Basic Surveys or Visual Encounter Searches (VES) are the most frequently used technique and are the standard method for pond-breeding amphibians (see Corn et al. 1989; Fellers 1997; Thoms et al. 1997). Search methods vary with site conditions. They involve visual searches and occasional use of a dip-net to check the shoreline and littoral environments. In smaller waters, habitats are completely sampled. For larger waters and complex habitats, subsampling is conducted (see below).

Surveyors orient to the site with the use of air photos or maps prepared from air

Table 3. Survey time (hours) allocated by habitat type for montane waters. These are actual times for surveys by a crew of two.

	Shallow Waters (<1 m deep)		Deep Waters (>1 m deep)	
	Small Ponds, Tarns, Potholes	Large Meadows, Wetland Complexes	Small Lakes, Large Ponds	Large Lakes
Survey Time				
General Time	0.5	1	1-2	2
Maximum	1	1	2	3
Survey	All areas	All areas	All shoreline	Shoreline by priority

photos. The recorder draws a field map of the selected site on mapform (part of the field form). Leave ample room to map waters found during 100-m periphery searches (described below). Determine the type of water (size, depth) and habitats to be surveyed (Table 3). We conduct surveys during times of maximum amphibian activity for anurans (generally 1000-2000 hrs).

Funnel Trapping

Overnight funnel trapping is an integral part of sampling because it provides additional presence information, especially on salamander larvae that often are cryptic or active at night. Also, trapping is a repeatable method (e.g., the number of traps per habitat patch is constant) that is less affected by observer biases than are other techniques (see Adams et al. 1997). Accessibility to, and around, sites can determine the extent of funnel trapping. We recommend use of traps at all study sites, except those that present dangerous conditions (e.g., steep shorelines, cliffs, ice fields) or that cannot be checked the next morning (e.g., a pothole 2 km away reachable only by a cross country trek). It is more efficient to sample accessible ponds and lakes than to spend time trying to reach remote sites or parts of sites.

We employ a new minnow trap: portable, mesh-net traps (ca. 0.4 m long) with square throats (0.2m on each side; Nylon Net Co.[1]). Preliminary field tests show equal or better capture rates in mesh traps than with wire screen traps (R. B. Bury and C. A. Pearl, pers. obs.). The main advantage of the mesh traps is their light weight and portability (they fold flat) compared to metal-wire or plastic minnow traps. We used no bait. We place traps so part of the trap is above the water line to avoid possible drowning of adult frogs or salamanders, which are occasionally caught in the traps. We secure traps to shore with cord and attach waterproof labels (name, project and scientific collecting permit number). Adams et al. (1997) provide guidelines for efficient trapping. We set a minimum of six traps for each site that only had rocky substrate (including gravel, silt). For sites with distinct habitats (e.g., shallows with vegetation or coarse woody debris), we set two traps for a 25 m^2 habitat unit and then added one trap each time the area of the habitat unit doubled (following the guidelines of Adams et al. (1997) or until all traps were used).

Periphery Survey

Unlike other techniques, we also survey a 100-m belt around the periphery of selected sites (Figure 2). We found that the 100-m sweep reveals small wetlands (marshes, wet meadows, ephemeral pools) that are absent on topographic or National Wetland Inventory maps. These are important habitats for amphibians (Table 4). Moreover, use of these habitats differ by species. For example, we found a high frequency of adult Cascade frogs occurred in lakes, but there was little evidence of eggs/tadpoles (Figure 3). The peripheral areas with small ponds had high occurrence of both adult frogs and their eggs/tadpoles (Figure 3).

We recorded presence and counts of

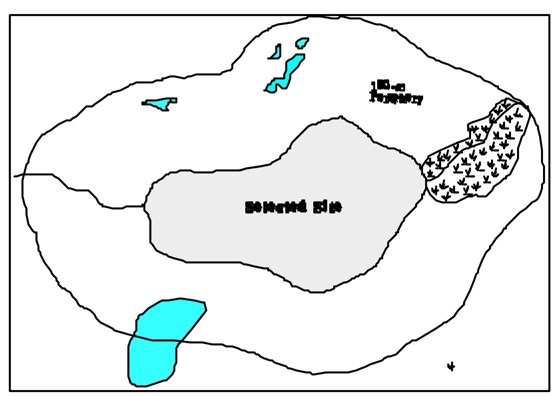

Figure 2. Schematic diagram of survey approach for an integrated sampling protocol.

Table 4. Frequency of occurrence of amphibian species by aquatic environment in summer 1996, Seven Lakes Basin, Olympic National Park, Washington.

	% Sites				
	No. Sites	*Ambystoma* spp	*Rana cascadae*	*Bufo boreas*	None
Lake	12	50	92	8	8
Pond	61	59	46	0	11
Meadow	7	57	71	0	29
Stream	13	8	62	8	23
Total	93	44	56	2	14

individuals for all amphibians and reptiles observed while walking in the peripheral area. The starting point and direction of searching for non-mapped waters are at the discretion of the field crew. For economy, we select every third wetland encountered within the 100-m area for a 'Basic Survey' (daytime search). If even part of the water body extends into the 100 m perimeter, the entire adjacent habitat is surveyed. Peripheral areas generally require <2 hr to survey per identified site.

Opportunistic Searches

Incidental records and observations of herpetofauna may document rare species or events (e.g., overland movements of anurans), and are always recorded in a field log. We record all observations of amphibians and reptiles while hiking, moving between sites, and around the 100-m sweeps of mapped sites.

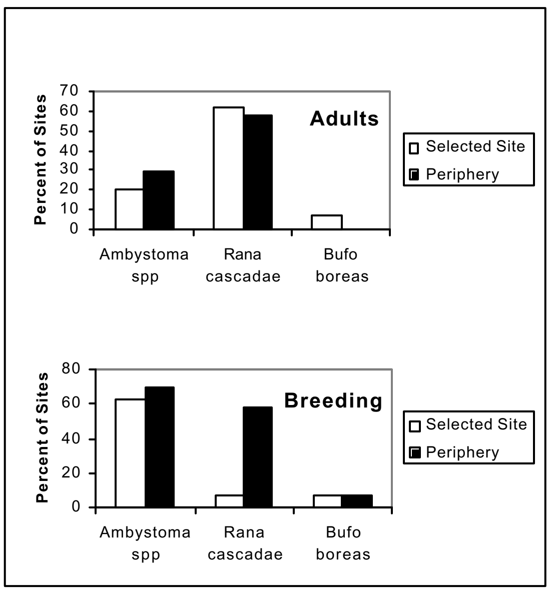

Figure 3. Frequency of occurrence (%) of amphibians by stage and survey area (Site vs. Periphery), Summer 1996, Seven Lakes Basin, WA.

General Habitat Criteria

Some sites may have areas that are unsafe to survey or are inaccessible (e.g., cliffs, water >1 m deep near shoreline, undercut banks); we do not survey them. For larger waters, we identify habitats that most likely harbor amphibians: cover (e.g., coarse woody debris or vegetation), shallows (sometimes with vegetation), and north shores. We survey these habitats first. Types of water sizes and habitats vary (Table 3), and are searched differently. The main types we encounter are listed below. In all cases, if animals are observed, we attempt to capture them for positive identification.

Many elements of pre-field work, survey logistics, and post-survey work discussed elsewhere (Fellers and Freel 1995; Bury and Major 1997; Crisafulli 1997; Fellers 1997; Thoms et al. 1997) apply to our sampling design. Only specific differences or emphasis are highlighted here.

Search by Water Size

Shallow ponds include waters with vegetation across the middle of the pond or where the shoreline lacks evidence of wave action. Generally, these are smaller-sized (1-2 ha maximum), but flooded meadows can be larger. These usually are sampled with 'Basic Surveys'.

Deep ponds (or lakes) are waters that are >1 m deep, lack vegetation in the middle, and often have a distinct shoreline (open or silt areas from wave action). For these larger waters, we subsample the shoreline with an Area Constrained Search (ACS). Details of these standard methods are provided elsewhere (Corn and Bury 1990; Bury and Corn 1991; Heyer et al. 1994b; Crisafulli 1997; Thoms et al. 1997). The level of effort for ACS and TCS depends on the location and types of habitats encountered (Table 3).

Search by Habitat Type

Open areas of rock, bedrock, sand or silt are searched by a 'Basic Survey'. Walk back and forth (zig-zag pattern) in water < 1-m deep and turn rocks along shoreline until you encounter another habitat type. Subsampling is necessary if the area is strewn with rocks or boulders. For example, subsample by turning all objects in 1-m^2 plots every 5 m of shoreline. Be sure to return rocks as close to their original position as possible. We conduct net sweeps every 5 m, even if no animals are visible (also see Crisafulli 1997; Thoms et al. 1997).

Aquatic vegetation (emergent or submergent) often occurs in bays and shallows of larger waters or entire ponds. To standardize, conduct 'Basic Surveys' that are timed based on the areal extent of the habitat. First, estimate the area of submerged and emerged vegetation in waters out to 1-m deep. Then survey based on a timed search per area of habitat (e.g., 1 min search per 1 m^2 of habitat); thus, if a habitat area has 42 m^2 (3 x 14 m area), search with the 'Basic Survey' for 42 min.

Coarse woody debris is searched with the same technique as for aquatic vegetation, but may require more effort because animals generally hide under cover objects. Carefully turn or move debris by hand or probe along edges of unmoveable objects with your hand or net (sometimes reveals animals). Be sure to return objects to their original position and place.

Logistics

Personnel should be a minimum of a two person crew: one to search in the littoral zone to 1-m deep and the other to survey along the shoreline and shallows as well as serve as recorder. The second person should stay 1-2 m back from the first biologist. If available, a third person can record data and map sites.

Coverage is usually two sites/day, depending on travel time, size of waters selected, and number of non-mapped waters found around the selected sites. We suggest a maximum of two days effort at any site (Table 3).

Frequency of Visits

Surveys dependent on a dichotomy (Presence/Not Found) can be misleading because many factors can affect the outcomes. For example, breeding phenology, weather, species detectability, and observer bias can greatly reduce the reliability of determining presence (Fellers 1997; Thoms et al. 1997). Many factors can be controlled by common sense or knowledge of species biology (see Nussbaum et al. 1983; Leonard et al. 1993; Fellers 1997; Olson and Leonard 1997). Thus, species presence obtained from one visit to a site may not reflect "true" richness. Two visits are recommended, especially where there are different species with early or late breeding seasons, which is often encountered with anurans.

Data Collection

Correct identification and measurement of captured animals is important. Data on individuals is recorded by: hand-capture, dip-netting, and visual observation. If >25 individuals of one species are captured and observed (positive identification, approximate sizes discernible), visually estimate if there are multiple sizes (age classes). If so, measure 10 of each size class. If not, measure 20 or more individuals until able to differentiate size classes.

Do accuracy checks. Upon completion of surveys, check data forms for errors, missing data, etc. (see also Thoms et al. 1997). Recheck upon return to base camp as time lags inevitably increase error rates (e.g., just where was that frog on Aug. 2nd at 0825 hrs). It is best if the same people who conducted the surveys enter the data into computer files.

Unresolved Issues

Observer Bias

Observer bias (or error) can greatly affect the reliability of collected data. Although a major issue with bird surveys, observer bias is seldom addressed for amphibians. Heyer et. al. (1994b) only briefly allude to the problem. Accuracy checks are vital for visual estimates of area, identification of species, measurements of captured individuals, etc. This information helps define the type and magnitude of error or bias in different observers. If deviations from the protocol are required, denote the change and what was done (e.g., the final 100 m of the lake was not surveyed because there was a bear with a cub on the shoreline). We need to strive to reduce observer bias by standardization of techniques, consistency in adherence to protocols, intensive field training, and employment of the same field crews over each field season (see Corn et al. 1989; Fellers and Freel 1995).

Detectability

We suggest that training be given priority because of the need to better develop species detectability indices and estimates of observer bias. Species detectability is a measure of the probability of detecting a species when it is present. A species that is widespread in occurrence and occurs in high numbers will be easier to detect than one that is patchily distribution or in low numbers. The behavior of species vary, too. We need to better understand how well the sampling method “detects” the species that occur at a study site, basin or region. This information is useful in determining modifications in survey intensity or incorporation of new techniques. An inventory protocol should include techniques that are fine scale enough to reveal 'rare' species (i.e., the sampling intensity or technique detects species that occur in low densities, are patchily distributed, or cryptic). If not, additional sampling techniques specific to these animals may need to be developed.

We strongly suggest that detectability estimates be determined at a few sites each year for any technique or protocol being used. At a minimum, sites should encompass simple versus complex habitats and varied species composition (few to many species and life history stages). Further, these sites should be visited throughout the season to identify possible temporal changes in species detectability.

Species detectability estimates have been developed for stream amphibians (Bury and Corn 1991), and briefly discussed elsewhere for amphibians (Heyer et al. 1994b). The reliability of this integrated protocol and almost all other techniques to detect "rare" species (e.g., those with low densities or patchy distributions) remains untested. Moreover, these estimates are particularly vital to build better sampling techniques and protocols for monitoring changes in amphibians over time.

SURVEY RESULTS

Association of Stream Amphibians with Climate Gradients and the Characteristics of Headwater Streams

Michael J. Adams and R. Bruce Bury

Introduction

Olympic National Park (ONP) provides a unique opportunity for study of ecological patterns along environmental gradients. It is situated on the Olympic Peninsula in Washington State, USA, and contains the bulk of the Olympic Mountains. The Olympic Mountains are isolated by water and low elevation areas from other ranges such as the Cascade Mountains (ca. 80 km east) and the Willipa Hills (ca. 60 km south), and are surrounded by the Pacific Ocean to the west, the Straight of Jaun de Fuca to the north, and Hood Canal and Puget Sound to the east. The Olympic Mountains rise to 2400 m and produce a pronounced rain shadow on their northeastern flanks. Because of this, average annual precipitation ranges from 6000 mm on the southwest side to 450 mm on the northeast side. This range produces a marked gradient from temperate rain forest to an area on the northeast coast that is sufficiently warm and dry to host a species of prickly-pear cactus, *Opuntia fragilis* (Buckingham et al. 1995).

A unique stream-amphibian fauna occurs in Olympic National Park and these species occupy large portions of its environmental gradients (Nussbaum et al. 1983). This fauna includes: *Ascaphus truei*, which is the sole member of the family Ascaphidae and considered the most primitive extant anuran in the world; and members of the families Dicamptodontidae (*Dicamptodon copei*) and Rhyacotritonidae (*Rhyacotriton olympicus*). All three taxonomic groups are endemic to the Pacific Northwest and are specialized for cold, torrential streams (Nussbaum and Tait 1977). They are sensitive to temperature and require permanent water for their multi-year larval stages (de Vlaming and Bury 1970; Nussbaum and Tait 1977; Bury and Adams 1999). *Dicamptodon copei* is peadomorphic and so, is especially reliant on permanent waters (Nussbaum et al. 1983).

Because of their unique zoogeographic status and their sensitivity to environmental changes (Welsh and Ollivier 1998), we documented their occurrence patterns in relation to physical habitat features, topographic features, and environmental gradients that might be affected by global change. ONP has been chosen by the National Park Service for ecosystem monitoring and long-term monitoring of amphibians is currently being established. Here, we report results of a 3-year survey that determined the distribution and abundance of stream breeding amphibians across environmental gradients in ONP. Our goal is to elucidate the environmental and habitat relationships of this unique fauna and to establish a baseline for future comparison.

Methods

We surveyed 141 headwater streams in 12 of 13 major drainages in ONP (Figure 4) in June – August, 1995 – 98. Because off trail access to ONP is difficult, we used roads and trails as a network of non-random transects covering the park. The population of streams from which study sites were chosen was determined by hiking the roads and trials in late summer or fall. Then, we randomly selected one third to one half of the streams that roads and main trials crossed within each drainage. We only chose from streams that appeared permanent. We did not survey large streams that appeared to have average depths over 30 cm because of inadequacies in our techniques and because smaller waters are the primary habitat for amphibians. In most drainages, we were

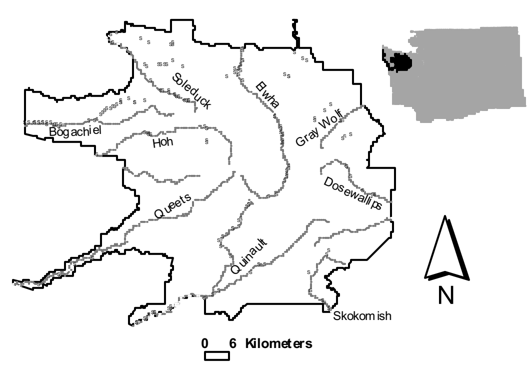

Figure 4. Stream survey sites in Olympic National Park.

able to survey all streams that were randomly chosen. In a few cases, weather and access problems precluded surveys of a few streams at relatively high elevations. Our site selection scheme did not provide statistical inference to the entire park. Rather, our conclusions are limited to the stream reaches directly above trails but the randomization served to reduce other forms of bias.

A crew of 2 or 4 people located randomly chosen streams and established a start point for the survey 30 m upstream of the trail. Then they randomly chose 10 1-m long segments of stream out of the next 100 meters. Each segment spanned the entire wetted width of the stream. The crew searched for amphibians in each chosen segment by overturning rocks and debris directly upstream from a dip net that was held against the substrate. Amphibians were then swept into the dip net by the current or were hand captured (Bury and Corn 1991). All animals were released at point of capture.

We recorded gradient at the center and both ends of each 100 m survey. We also recorded aspect and weather conditions at the start of the survey. We recorded 6 habitat variables at every 1-m segment: (1) stream width; (2) depth at three equidistant points spanning the width of the stream; (3) the percent of the segment's area that was judged fast flowing; (4) dominant and subdominant substrate types (16 categories following the Cummins (1962) modification of the Wentworth scale (Wentworth 1922)); (5) the percent of the segment covered by each of coarse woody debris, organic debris other than coarse wood, and undercut bank; and (6) the percent of the segment covered by overhanging vegetative structure.

Statistical Analysis

We compared the relative abundance (number/segment) of each species of stream amphibian to stream variables by analysis of deviance (ANODEV) using GLIM 4.0 (Francis et al. 1993). ANODEV is equivalent to analysis of variance when normal error is used, but uses maximum likelihood rather than least-squares estimation and thus, can accommodate error distributions other than normal. We specified Poisson error and used F-tests, rather than chi-square, to compensate for overdispersion (Smith 1991). We used a log link to make the model linear (i.e., these were log-linear models; Aitkin et al. 1989).

To determine the association between stream amphibian distributions and climate gradients, we used climate predictions from PRISM climate models. PRISM generates gridded estimates of climate parameters based on point data and a digital elevation model (Daly et al. 1994). It is designed to account for the effect that mountainous terrain has on climate. We used the average number of individuals/segment for each PRISM grid cell as the response variable for each species of stream amphibian. The climate variables we analyzed were mean annual precipitation, mean annual

Table 5. The mean and standard deviation (SD) of captures per m^2 for stream amphibian surveys in Olympic National Park, 1996-98. N = number of streams sampled. Only larvae and peadomorphs are included.

		Ascaphus truei		*Rhyacotriton olympicus*		*Dicamptodon copei*	
Drainage	N	mean	SD	mean	SD	mean	SD
North Fork Soleduck	8	0.522	1.279	0.147	0.368	0.401	0.669
Soleduck	13	0.049	0.158	0.106	0.449	0.106	0.360
Bogachiel	26	0.289	0.811	0.390	0.917	0.208	0.539
Hoh	6	0.204	0.741	0.041	0.196	0.013	0.072
Queets	5	0.012	0.070	0.207	0.565	0.159	0.446
Lake Quinault	11	0.049	0.168	0.010	0.062	0.063	0.202
North Fork Quinault	12	0.229	0.673	0.204	0.514	0.277	0.668
East Fork Quinault	6	0.091	0.306	0.241	0.388	0.161	0.568
Skokomish	4	0.205	0.672	0.157	0.417	0.147	0.438
Dosewallips	5	0.379	0.704	0.015	0.113	0.000	0.000
Gray Wolf	8	0.897	1.383	0.000	0.000	0.000	0.000
Morse	5	1.341	2.104	0.070	0.206	0.000	0.000
Elwha	27	0.403	0.835	0.352	0.658	0.000	0.000
Lyre	5	2.568	3.167	0.376	1.011	0.000	0.000
All Drainages Combined	142	0.390	1.089	0.200	0.583	0.110	0.402

Table 6. Analysis of deviance in amphibian abundance among streams in Olympic National Park. Response variable is the average number of captures per m^2. Models are log-linear with Poisson error. Numbers are for univariate models.

Source	df	Dev	F	P	coef.	SE
Ascaphus truei						
Total	140	130.7				
Elevation	1	5.96	6.65	**0.011**	0.0003	0.0001
Aspect	1	15.52	18.74	**<0.001**	-0.0091	0.0023
Width	1	0.10	0.10	0.748	0.0004	0.0012
Gradient	1	1.06	1.14	0.288	0.0081	0.0077
Depth	1	2.83	3.08	0.082	0.0388	0.0213
Coarse Wood	1	0.32	0.34	0.559	-0.5400	0.9588
Organic Debris	1	29.78	41.03	**<0.001**	-5.0020	1.0700
Undercut Bank	1	5.35	5.94	**0.016**	-1.2790	0.5608
Canopy Cover	1	2.26	2.45	0.120	0.6367	0.4274
Substrate Factor	1	20.83	26.36	**<0.001**	-1.1040	0.3042
Rhyacotriton olympicus						
Total	140	89.27				
Elevation	1	0.21	0.33	0.567	<-0.0001	0.00015
Aspect	1	13.68	25.16	**<0.001**	-0.0105	0.0029
Width	1	1.56	2.46	0.119	-0.0021	0.0017
Gradient	1	14.65	27.29	**<0.001**	0.0342	0.0087
Depth	1	26.11	57.46	**<0.001**	-0.2695	0.0635
Coarse Wood	1	10.11	17.75	**<0.001**	3.2340	0.9619
Organic Debris	1	<0.01	<0.01	0.982	-0.0148	0.7907
Undercut Bank	1	2.38	3.80	**0.053**	-1.0270	0.6733
Canopy Cover	1	1.44	2.27	0.134	0.6144	0.5177
Substrate Factor	1	12.20	22.00	**<0.001**	-0.9803	0.3547
Dicamptodon copei						
Total	140	44.99				
Elevation	1	0.01	0.02	0.896	<-0.0001	0.0002
Aspect	1	0.60	1.87	0.174	0.0035	0.0046
Width	1	2.37	7.73	**0.006**	-0.0044	0.0031
Gradient	1	<0.01	<0.01	0.956	0.0002	0.0155
Depth	1	1.48	4.73	**0.031**	-0.0760	0.0680
Coarse Wood	1	0.47	1.46	0.229	-1.2820	1.908
Organic Debris	1	0.21	0.66	0.418	0.5547	1.1770
Undercut Bank	1	0.08	0.23	0.631	0.2838	1.0360
Canopy Cover	1	1.27	4.05	**0.046**	-0.8916	0.7887
Substrate Factor	1	0.29	0.90	0.344	0.1221	0.2163

temperature, mean heating degree days, and mean growing season length. They were based on data collected from 1961-1990. We used ANODEV with Poisson error and a log link for the analysis. We weighted each cell by the number of streams surveyed. We used an F-test to compensate for overdispersion and considered factors significant at $\alpha = 0.05$. We used forward selection to determine the best model and included interactions and quadratic terms until no more significant factors could be found.

Because *D. copei* was not detected in cells from 4 drainages on the northeast side of the park in both historic records and our surveys, we hypothesized that its absence from this region was consistent with *D. copei*'s relationship to climate in the rest of the park. In other words, we hypothesized no significant difference in the form of the models derived with (model 1) and without (model 2) the zeros from the 4 drainages where *D. copei* was absent.

To test this hypothesis, we fit the significant climate variables from model 1 in model 2. We then measured the change in deviance that occurred when the three climate parameters were offset using the coefficients from model 1. Offsetting is a generalized linear modeling approach that allows one to specify, rather than fit, one or more parameter coefficients in a model

(McCullagh and Nelder 1989). Thus, we compared the residual deviance in model 2, when parameter coefficients were estimated, to when the parameter coefficients that resulted from model 1 were forced into the model. A significant change in deviance suggests that the absence of *D. copei* in our samples from the northeast portion of the park is not consistent with its relationship to climate in the rest of the park. However, we caution that cause and effect cannot be established using correlative analyses. We did not omit cells that overlapped the Lyre River drainage in model 2 because these overlapped the North Fork of the Soleduck and had *D. copei* present.

Results

Stream Variables

All three species differed in abundance among drainages (Table 5). *Dicamptodon copei* was not detected in any of the five northeast drainages. *Rhyacotriton olympicus* was not detected in the Gray Wolf. *Ascaphus truei* was detected in all drainages surveyed.

ANODEV revealed significant associations with topographic variables for *A. truei* and *R. olympicus* but not for *D. copei* (Table 6). *Ascaphus truei* and *R. olympicus* were both more abundant in streams with northern aspects (Figure 5). *Rhyacotriton olympicus* had a strong association with steep gradients. *Ascaphus truei* had a positive association with elevation but appeared most abundant at middle elevations.

Physical stream variables were the best predictors of amphibian density (Table 6). *Ascaphus truei* and *R. olympicus* both had negative associations with fine substrates (Figure 6) and undercut banks. They differed in that *A. truei* had a strong negative association with organic debris while *R. olympicus* had a strong positive association with coarse woody debris. But, the positive association with coarse woody debris appeared to be from an outlier. *Dicamptodon copei* was associated with shallow, narrow streams, but showed no relationship to organic debris of any kind. *Dicamptodon copei* was also associated with relatively open canopy cover.

Climate Variables

Ascaphus truei was associated with greater heating degree days and lower precipitation (Table 7). *Rhyacotriton olympicus* and *D. copei* both had quadratic

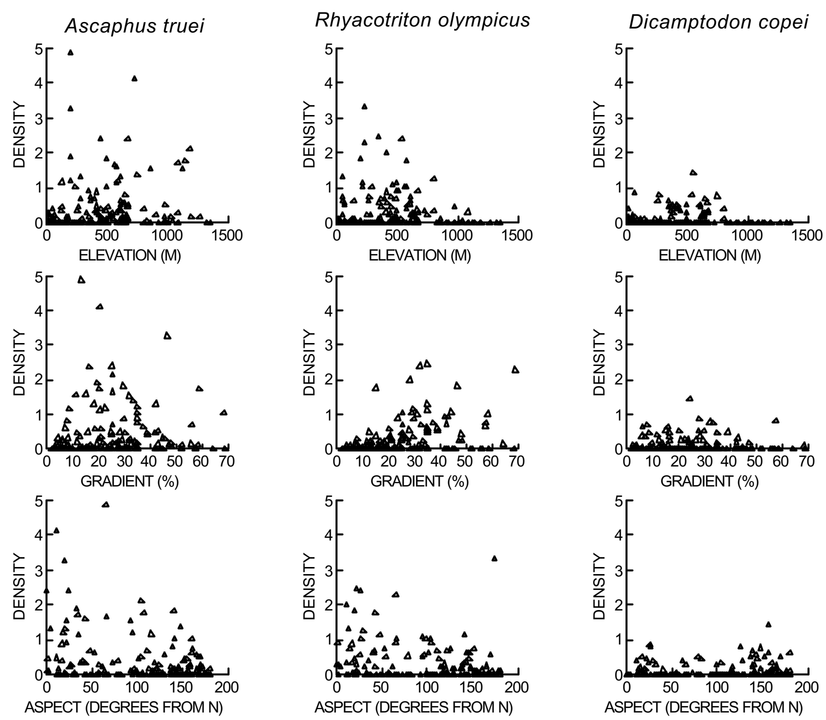

Figure 5. Association of stream amphibians with stream topographic variables. Density is number captured per m^2.

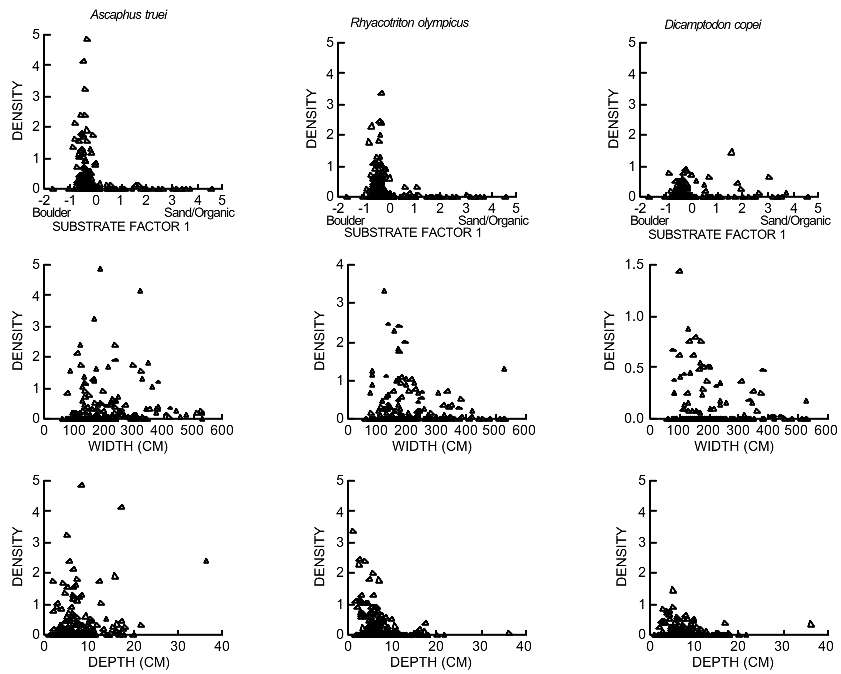

Figure 6. The association between stream amphibians and three stream variables: substrate, gradient, and depth. Substrate is a principle components factor describing a gradient from large cobble to fine sand and organic substrates. Density is number captured per m^2.

associations with growing-season length (Table 7). They were more abundant in PRISM cells with longer growing seasons (Figure 7). *Dicamptodon copei* was also more abundant in cells with higher precipitation. The relationship between *D. copei* and climate was significantly different when cells from the northeastern portion of the park were omitted (change in deviance = 4.643, $F_{3,39}$ = 3.365, P = 0.028). Specifically, the positive correlation between *D. copei* abundance and precipitation was no longer significant when the cells from the northeastern corner of the ONP were omitted. The quadratic relationship between *D. copei* and growing-season length remained similar (Figure 7).

Discussion

The stream amphibians of the Pacific Northwest are a highly specialized and environmentally sensitive assemblage that is unique worldwide in its adaptation to torrential habitats (Noble 1927). While similar in their specialization for torrential habitats, the three stream-breeding families appear to differ in their environmental tolerance. This is evidenced by their geographic ranges (Nussbaum et al. 1983): Ascaphidae has the broadest range in terms of both latitude and longitude and occupies both coastal and inland environmental regimes including the Rocky and Blue mountains; the range of Dicamptodontidae also extends inland but does not include the Rocky or Blue mountains; Rhyacotritonidae is confined to the Cascade and Coastal mountain ranges.

We found that both stream characteristics and climate conditions are associated with the distributions of the three stream amphibian species in ONP, but the importance of these two factors varied among species. Their relationship to the environmental gradients in ONP appeared to reflect broader distribution patterns.

Ascaphus truei was closely associated with the physical attributes of streams. Cobble substrate was the most important stream characteristic that predicted high abundance of *A. truei*. This is consistent with previous findings (Bury 1968; Corn and Bury 1989; Welsh et al. 1997; Diller and Wallace 1999). Cobble substrates provide smooth surfaces for the suctorial tadpoles to cling to and feed on (Gradwell 1971). They also provide interstices for cover (Feminella and Hawkins 1994). The lack of an association with stream gradient was surprising as *A. truei* is generally thought to be associated with steep gradients. Visual inspection of our

Table 7. Analysis of deviance in abundance of stream amphibians in 2×2-km cells within Olympic National Park. Response variables are the number of mean stream amphibians captured per m^2 averaged over all streams in a cell. Models are log-linear with Poisson error and are weighted by the number of streams in each cell. See methods for description of *D. cope*i models 1 and 2.

Source	df	Dev(cum)	F	P	coef.	SE
Ascaphus truei						
Heating	1,58	10.370	7.031	0.010	0.0003	0.0001
Precipitation	1,57	7.006	4.750	0.033	-3.6×10^{-6}	1.4×10^{-6}
Residual	57					
Rhyacotriton olympicus						
Growing	1,58	6.187	6.242	0.015	0.610	0.295
Growing^2	1,57	5.474	5.998	0.017	-0.0017	0.0009
Residual	57	52.019				
Dicamptodon copei (model 1)						
Precipitation	1,58	7.127	19.863	<0.001	1.0×10^{-5}	4.1×10^{-6}
Growing	1,57	6.459	18.001	<0.001	1.055	0.6452
Growing^2	1,56	3.421	9.534	0.003	-0.003	0.0019
Residual	56	20.093				
Dicamptodon copei (model 2)						
Precipitation	1,41	0.870	1.891	0.177	8.6×10^{-6}	4.6×10^{-6}
Growing	1,40	3.300	7.174	0.011	0.950	0.650
Growing^2	1,39	2.662	5.787	0.021	-0.003	0.0019
Residual	39	17.940				

data suggests *A. truei* is tolerant of a wide range of stream gradients but is most abundent at gradients around 20% (Figure 5).

In contrast to *A. truei*, *D. copei* appeared a habitat generalist but was closely associated with climate. Several lines of evidence suggest that the apparent absence of *D. copei* from the northeastern portion of the park might be cause for concern. First, *D. copei* appears to tolerate a wide range of environmental conditions. For example, we found no critical habitat predictors of *D. copei* abundance and streams in the northeastern portion of the park did not differ substantially from the remainder of the park. Second, while *D. copei*'s distribution appears superficially to match the main southwest to northeast climatic gradient, our analysis suggest that *D. copei*'s distribution is not simply a result of this climate gradient. Rather, the model relating *D. copei* abundance to climate changes significantly when the northeastern portion of the park is omitted. Moreover, the Dicamptodontidae as a group occur over a broad geographic range, similar to Ascaphidae, and appear tolerant of the drier, warmer climate prevalent in the northeastern portion of ONP (e.g., their range includes the Rocky Mountains). Finally, *D. copei*'s association with open canopy and its tolerance of southern aspects indicates a greater tolerance of solar input than the other two species of stream amphibian. This finding is inconsistent with the absence of *D. copei* from the warmer, dryer portion of the park.

Despite these arguments, there is only a single historic record of *D. copei* from a low elevation area northeast of ONP (Nussbaum, et al. 1983) and there are no records from inside the park in any of the drainages where we failed to detect *D. copei*. We cannot conclude that the distribution of *D. copei* has changed substantially in the past century. There is always a strong possibility in studies such as this, that other unexamined factors limit the distribution of *D. copei*. We suggest that our findings give cause for closer examination of *D. copei* distribution patterns and active monitoring of *D. copei* populations. Further, we suggest investigation of potential anthropogenic factors that could negatively impact *D. copei* such as airborne pollutants. Finally, we hypothesize that greater hydrological fluctuations in the northeast portion of the park are limiting stream amphibians. We would expect that *D. copei* would be the most sensitive to such fluctuations because, unlike *A. truei* and *R. olympicus*, it is largely peadomorphic and

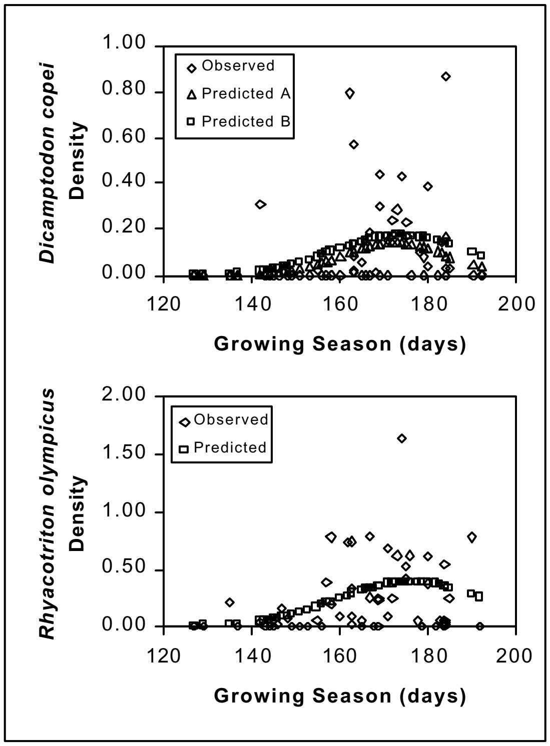

Figure 7. The association between stream salamanders and growing season length in Olympic National Park. Density is number captured per m^2.

should have the lowest tolerance of stream drying.

Rhyacotriton olympicus was associated with both habitat and climate. It was rare, but present, in the northeastern portion of the park and had a similar quadratic association with growing season length to *D. copei* (Figure 7). *Rhyacotriton olympicus* was also strongly associated with physical stream variables. In general, *R. olympicus* was most abundant in steep, shallow streams with cobble substrates. its density appeared to peak in steams with gradients of about 35%.

These findings are consistent with previous studies that suggest substrate is important to stream amphibians (Corn and Bury 1989; Diller and Wallace 1999). The association of these species with some of the pronounced climatic gradients in ONP suggests that they may be indicator species for global climate change. However, we caution that cause and effect has not been demonstrated and the associations with climate may be spurious. We suggest continued monitoring of stream-amphibian abundance and larval life history characteristics, and further study of the mechanisms that limit their populations.

Association of Amphibians with Characteristics of Montane Ponds.

Michael J. Adams, Daniel E. Schindler, R. Bruce Bury

Declines in amphibian populations have been reported worldwide and in areas relatively protected from obvious human disturbance (e.g., Corn et al. 1989; Crump et al. 1992; Drost and Fellers 1996; Lips 1998). One hypothesis to explain some of these declines is that increases in surface ultraviolet-b radiation (UV-B) are negatively impacting amphibians (Blaustein et al. 1994a). Stratospheric ozone depletion has caused surface UV-B levels at northern temperate latitudes to increase by >1% per year in recent decades (Blumthaler and Ambach 1990). Many studies have demonstrated the potential for ambient or enhanced UV-B to be damaging to amphibians and other organisms in laboratory studies (Worrest and Kimeldorf 1976; Grant and Licht 1995; Ankley et al. 1998). However, natural habitats and variation in UV-B levels provide numerous opportunities for amphibians to mediate their exposure in natural systems.

Blaustein et al. (1994a) found that the vulnerability of Pacific Northwest amphibians to UV-B damage correlated with the activity levels of the enzyme photolyase. Interspecific differences in sensitivity to UV-B are consistent with field experiments (outdoors with ambient UV-B) that have shown negative effects of UV-B on a number of species of amphibian larvae: *Bufo boreas*, *Rana cascadae*, *Ambystoma gracile* (Blaustein et al. 1994a; Blaustein et al. 1995), *Litorea aurea* (van de Mortel and Buttemer 1996), and *Bufo bufo* (Lizana and Pedraza 1998); no effects were found for *Rana aurora* and *Hyla regilla* (Blaustein et al. 1994a; Blaustein et al. 1996; Ovaska et al. 1997) or *Litorea preonii* and *L. dentata* (van de Mortel and Butemer 1996). Two instances where multiple tests were conducted for the same species gave conflicting results (*Bufo boreas*, Blaustein et al. 1994 vs. Corn 1998; *Litorea aurorea*, two tests by van de Mortel and Buttemer 1996), but different results might be due to variation in ambient UV-B levels.

While some of these studies show the potential for UV-B to be related to amphibian declines, there is currently no evidence that the spatial distribution of amphibian populations is associated with UV-B exposure. If recent increases in surface UV-B are contributing to amphibian declines, then populations of affected amphibians should be more likely to persist in ponds that are relatively protected from UV-B. Here, we examine whether the distribution of amphibian breeding populations correlates with the UV-B attenuation properties of water in an area lacking obvious habitat degradation.

Pond-breeding amphibians often deposit eggs in shallow waters where embryos and larvae are exposed to direct sunlight. Aside from direct shading on or under the water, dissolved organic matter (DOM) is the main compound that attenuates UV-B in water and can have dramatic effects on UV-B penetration into the water column (Skully and Lean 1994, Morris et al. 1995). For example, a decrease in the concentration of DOM from 2 mg/L to 1 mg/L increases the exposure to 305-nm radiation at 0.5 m depth from 4% to 25% of surface irradiance (Morris et al. 1995). Given the strong affect of DOM on UV-B exposure in the water column, we investigated the association between UV-B attenuation and amphibian distribution in remote ponds of Olympic National Park where there has been minimal habitat alterations or other human disturbances.

Methods

We surveyed lentic habitats in Olympic National Park, Washington, USA (ONP) from 1996–1998. We randomly selected sites within 6 regions that were deliberately chosen to maximize geographic coverage of ONP (Figure 8). All lentic habitats appearing on National Wetlands Inventory and USGS topological maps of these regions were in the population of lentic habitats from which study sites were selected. To partially offset bias from missing unmapped waters, we also surveyed all unmapped waters occurring within 100 m of any chosen site (Bury and Major 1997).

We surveyed for amphibians from July to early September using a visual encounter technique (Bury and Major 1997). Two people slowly walked the perimeter of each site in

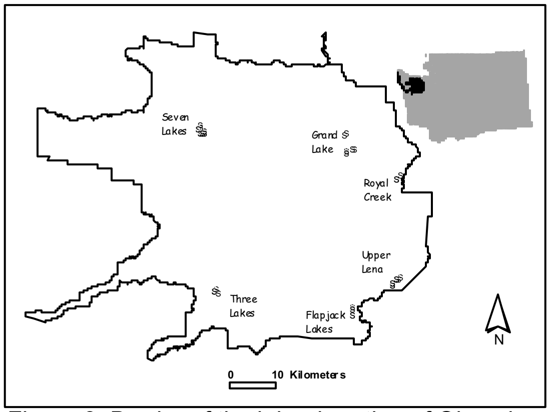

Figure 8. Border of the inland portion of Olympic National Park and regions selected for pond surveys in 1997-98. Olympic National Park is centered at 48°50' N latitude and 123°35' W longitude on the Olympic Peninsula in Washington State, USA.

tandem, one wading in the littoral zone and one on shore, recording the species and stage of amphibians encountered. Surveyors supplemented visual encounters by thoroughly searching 1 m^2 of substrate every 10 m, lifting and replacing any rocks or organic debris that could shelter amphibians. Workers used a dip net to sweep through vegetation or loose substrate.

Finally, we set collapsible funnel traps (25 × 25 × 36 cm) in shallow waters of most sites. Shallow waters (<30-cm deep) were split into 2–5 major habitat types based on vegetation, substrate, and aspect, and traps were allocated to each habitat type following Adams et al. (1997): 2 traps for a 25 m^2 habitat and an additional trap each time the area doubles. Some small ponds were not trapped because they were easy to search and trap numbers were limited.

We categorized maximum pond depth as <1m, 1-2m, or >2m. We categorized the extent of emergent vegetation around the perimeter of each site as 0-25%, 25-50%, or >50%. We recorded the dominant substrate type of littoral habitats. All of the waters surveyed were historically fishless but some had eastern brook trout (*Salvelinus fontinalis*) and possibly other salmonids introduced. We categorized each site as fish detected or not based on visual observations (queries of backcountry rangers indicated that our visual observations never missed presence of known fish populations).

Prior to analysis, we collapsed categories within the vegetation and substrate variables to produce variables with approximately equal numbers of ponds in each category. This resulted in two binomial variables: presence of emergent vegetation and presence of silt-mud as the dominant substrate type.

We collected a 50 ml water sample from the midpoint of the water column in the littoral zone of each site; one sample from most ponds, but 2 from 6 ponds in the Seven Lakes region. Samples were kept cool and in the dark, and then frozen as soon as possible after collection (3–10 d). We inferred UV-B exposure to amphibians by estimating the attenuation of 305 and 320-nm radiation by dissolved organic matter (DOM) in pond water as outlined by Morris et al. (1995). In brief, each sample was thawed and a 30 ml sub-sample was filtered through a Corning 0.20 μm pore, 25 mm diameter Nylon filter. Each filtered sub-sample was then transferred to a quartz cuvette and the percent absorbence at 440 nm (a_{440}) was measured in a Perkin-Elmer double beam spectrophotometer with a 10-cm path length. The diffuse attenuation coefficient (K_d) at 305 nm and 320 nm were calculated from a_{440} following equations given in Morris et al. (1995): $K_{d305} = 24.4(a_{440}) - 0.99$, $K_{d320} = 16.0(a_{440}) - 0.15$. The proportion of incident

Table 8. Number of ponds with breeding populations (and total ponds where any stage was detected) of amphibians from surveys in Olympic National Park. N = number of ponds surveyed. Weeks 1--12 = first week in July – last week in September.

	Ambystoma gracile	*A. macrodactylum*	*Dicamptodon copei*	*Taricha granulosa*	*Hyla regilla*	*Rana cascadae*	N	Elevation Range (m)	Week Sampled
Seven Lakes	4 (4)	7 (7)	1 (1)	0 (1)	0 (0)	5 (9)	14	1158-1523	3--9,11
Grand Lake	0 (0)	4 (4)	0 (0)	0 (0)	0 (0)	4 (5)	5	1249-1843	4
Royal Creek	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	2 (4)	4	1554-1737	10
Upper Lena	4 (4)	5 (6)	0 (0)	0 (0)	0 (1)	5 (13)	13	1402-1508	11,12
Flapjack Lake	3 (3)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2)	3	1188-1322	7
Three Lakes	3 (3)	0 (0)	0 (0)	0 (2)	2 (2)	2 (3)	3	900-1050	5
Total	14 (14)	17 (18)	1 (1)	0 (3)	2 (3)	19 (36)	42	900-1843	1—12

radiation at a certain water depth (L_z) was calculated for 305 and 320-nm radiation according to: $L_z = e^{-Kd.Z}$, where Z is the depth in the water column.

We used GLIM 4.0 to examine the association between the presence of amphibian breeding populations (eggs or larvae detected) and pond characteristics for each species of amphibian that was detected at more than 30% of the sites (Aitkin et al. 1989). We considered pond characteristics significant at α = 0.05, but also report relationships with $P < 0.10$. We specified binomial error and used a logit link to make the models linear. We also examined the ability of UV-B variables to explain additional deviance after other significant variables had been entered in the models. We used Chi-square probabilities to test significance.

Results

We detected 6 species of amphibian and 3 of these were sufficiently common for further analysis (Table 8). These 3 species all range throughout the Olympic Peninsula and can be found over the entire range of

Table 9. Association of amphibian breeding populations with characteristics of 42 ponds in Olympic National Park. UV-B variables are expressed as wavelength (nm) @ depth (cm).

Source	df	Dev	*P*	Coefficient	SE
Rana cascadae					
Total	41	57.843			
Fish	1	3.609	**0.057**	-1.848	1.1120
Depth	2	6.680	**0.035**		
1-2 m				-0.730	0.8751
>2 m				-2.051	0.8846
Silt/Mud	1	8.566	**0.003**	1.950	0.7126
Vegetation	1	1.161	0.281	0.742	0.6940
Elevation	1	0.118	0.731	0.000	0.0003
305nm@50cm	1	4.318	**0.038**	-1.797	0.9255
320nm@50cm	1	4.838	**0.028**	-2.087	1.0280
305nm@10cm	1	4.443	**0.035**	-2.030	1.0040
320nm@10cm	1	5.246	**0.022**	-2.590	1.2000
Ambystoma gracile					
Total	41	53.467			
Fish	1	0.332	0.564	0.493	0.8460
Depth	2	1.203	0.548		
1-2 m				0.754	0.8991
>2 m				0.705	0.7536
Silt/Mud	1	5.052	**0.025**	1.587	0.7533
Vegetation	1	8.167	**0.004**	2.079	0.7634
Elevation	1	17.400	**< 0.001**	-0.003	0.0012
305nm@50cm	1	0.184	0.668	-0.369	0.8675
320nm@50cm	1	0.266	0.606	-0.482	0.9452
305nm@10cm	1	0.238	0.626	-0.476	0.9763
320nm@10cm	1	0.278	0.598	-0.592	1.122
Ambystoma macrodactylum					
Total	41	51.972			
Fish	1	5.790	**0.016**	-8.040	16.6200
Depth	2	0.733	0.392		
1-2 m				0.754	0.8991
>2 m				0.348	0.7744
Silt/Mud	1	0.562	0.453	-0.503	0.6717
Vegetation	1	4.708	**0.030**	-1.991	1.089
Elevation	1	9.498	**0.002**	0.002	0.008
305nm@50cm	1	0.581	0.446	0.648	0.8471
320nm@50cm	1	0.639	0.424	0.737	0.9182
305nm@10cm	1	0.433	0.511	0.663	1.0150
320nm@10cm	1	0.518	0.472	0.846	1.192

Table 10. Significance of pairwise associations among predictor variables. Values are Likelihood Ratio *P*-values when both predictors are categorical, Pearson *P*-values when at least 1 variable is continuous, and *F*-ratio *P*-values for comparing depth (which had 3 categories) to continuous variables. Sign indicates direction of association. UV-B attenuation variables were all highly correlated among themselves ($P < 0.001$ for all).

	Depth	Silt/Mud	Veget-ation	Eleva-tion	305@50 cm	350@50 cm	305@10 cm	350@10 cm
Fish	**<0.001(+)**	**0.015(-)**	0.094(+)	0.671(-)	0.139(+)	0.164(+)	**0.053(+)**	0.067(+)
Depth		**0.001(-)**	0.847(+)	0.998(-)	**0.002(+)**	**0.004(+)**	**0.005(+)**	**0.007(+)**
Silt/Mud			0.929(+)	0.129(-)	**0.044(-)**	**0.039(-)**	**0.010(-)**	**0.009(-)**
Vegetation				**0.015(-)**	0.067(-)	0.057(-)	0.063(-)	**0.052(-)**
Elevation					0.061(+)	**0.042(+)**	**0.012(+)**	**0.006(+)**

elevations we sampled (Nussbaum et al. 1983).

Rana cascadae was most common in shallow ponds with a silt-mud substrate that had high UV-B attenuation and that lacked fish (Table 9). These characteristics covaried (Table 10). With depth and substrate in the model, the presence of *Ambystoma gracile* had a significant negative influence on *R. cascadae* presence (Dev = 3.745, df = 1,37, $P = 0.053$). Residual deviance (42.259) was still greater than residual df (37), but no other variables or interactions were significant.

The negative association between *R. cascadae* and the four UV-B attenuation variables was still present after the presence of fish was entered in the model (Figure 9; $P = 0.063$—0.100), but not after depth or substrate was entered ($P > 0.15$ for all). The attenuation of 320 nm radiation at 10 cm was the most significant UV-B variable (Table 9). Its mean value was 0.729 (SE = 0.060) at ponds without *R. cascadae* and 0.526 (SE = 0.099) at ponds with *R. cascadae*.

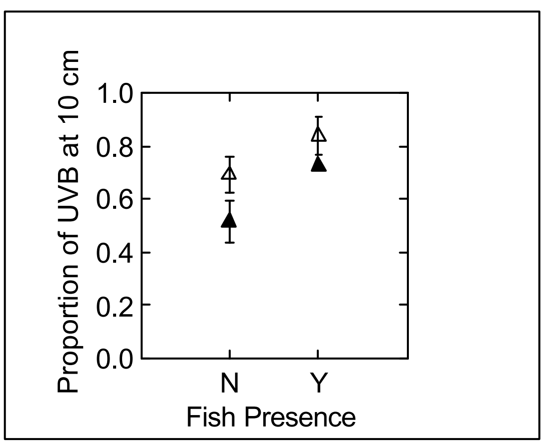

Figure 9. Mean estimated proportion (+/- SE) of incident 320-nm radiation remaining at 10 cm water-depth for ponds with (filled triangles) and without (open triangles) a breeding population of *Rana cascadae* in Olympic National Park, 1997-98.

Ambystoma gracile was most common at lower elevation ponds and at ponds with emergent vegetation and silt-mud substrates (Figure 10; Table 9). They were not associated with UV-B attenuation or the presence of fish. Substrate was still

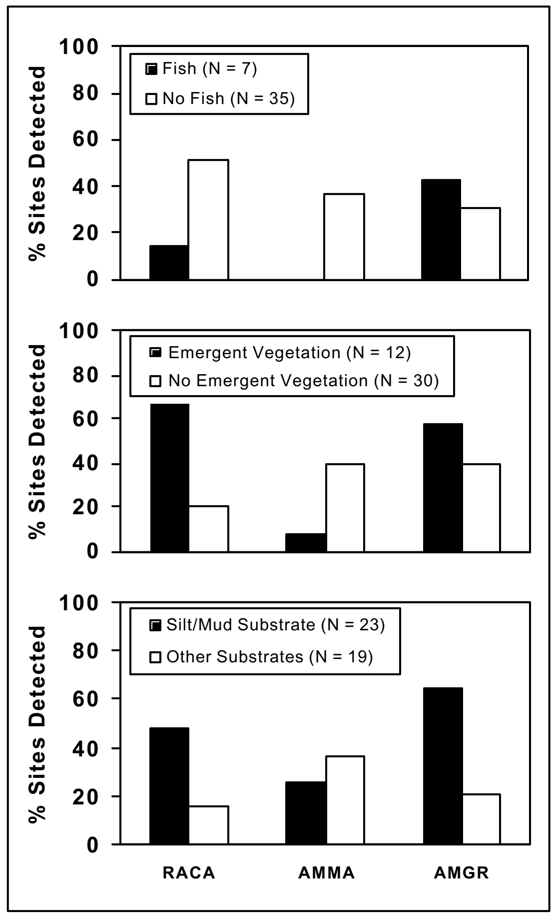

Figure 10. Relationship between amphibian occurrence and fish presence, vegetation, and substrate at 42 ponds in Olympic National Park, 1997-98. Y-axis shows the percent of the sites in each category where each species occurred. RACA = *Rana cascadae*; AMMA = *Ambystoma macrodactylum*; and AMGR = *A. gracile*.

significant after elevation was entered in the model (Dev = 3.753, df = 1,39, P = 0.053). Residual deviance (36.071) was less than residual df (40) when only elevation was in the model. A slight negative association between *A. gracile* presence and UV-B attenuation was not significant after any of the significant variables were entered (P > 0.5 for all).

Ambystoma macrodactylum were most common at higher elevation ponds and in ponds without fish or emergent vegetation (Figure 10; Table 9). They were not associated with UV-B attenuation. Fish had a moderately significant negative effect after elevation was entered (Dev = 3.486, df = 1,39, P = 0.062). Residual deviance (38.988) and residual df (39) were approximately equal when elevation and fish were in the model. A slight positive association between *A. macrodactylum* presence and UV-B attenuation was not significant after any of the significant variables were entered (P > 0.15 for all).

Discussion

The 3 species of amphibian we analyzed differed markedly in their occurrence patterns (Figure 10), 2 of which were not associated with UV-B attenuation (*A. gracile* and *A. macrodactylum*). However, occurrence of *R. cascadae* breeding populations was positively associated with relatively high attenuation of UV-B. Our data did not show that UV-B was the mechanism that caused the observed spatial distribution of *R. cascadae* in ONP. Rather, *R. cascadae* tended to have breeding populations at shallow ponds with silt/mud bottoms that lacked fish. These ponds had relatively high DOM levels. Our data did not allow separation of these factors, but attenuation of UV-B remained a moderately significant predictor of *R. cascadae* breeding after accounting for the presence of fish (Figure 9).

The absence of any association between *A. gracile* and UV-B attenuation in our surveys is surprising given that Blaustein et al. (1995) found lower survival of embryos in ambient compared to UV-B filtered light. This discrepancy in our study may suggest among population variability in UV-B sensitivity. Alternatively, the positive association with the presence of emergent vegetation (Figure 10) might suggest that shading structures in ponds facilitate the survival of *A. gracile* embryos in their natural environments. However, structure that could shade littoral habitats was rare and vegetation, even when present, was generally sparse. It is also possible that *A. gracile* modify their behavior to avoid exposure to high levels of UV-B.

Likewise, Blaustein et al. (Blaustein et al. 1997) found higher survival and lower deformity rates in *A. macrodactylum* embryos that were experimentally sheltered from UV-B. We did not find a relation between *A. macrodactylum* occurrence and the UV-B attenuation properties of ponds, but this species may limit its exposure to UV-B in other ways. For example, eggs and larvae could be sheltered from UV-B by shading structure in ponds. Our findings are consistent with reports of a negative effect of introduced fish on *A. macrodactylum* (Tyler et al. 1998a; Tyler et al. 1998b).

Our data should not be interpreted as indicative of absolute levels of UV-B attenuation in ponds. Rather, DOM changes seasonally and annually, and DOM in water samples degrades with time after collecting. Our data provide an index of variability in UV-B attenuation among ponds, but more research is needed to determine DOM type and levels before UV-B attenuation can be accurately estimated. Moreover, we need to examine how amphibians behaviorally mediate their exposure to UV-B. For example, yellow perch spawn deeper in water with high attenuation of ultraviolet radiation (Williamson et al. 1997), and zooplankton may adjust diel vertical migrations to regulate their exposure to UV-B (Williamson et al. 1994).

We do not know of evidence that *R. cascadae* has declined in Olympic National Park. Rather, *R. cascadae* was the most common pond-breeding amphibian and were found throughout ONP (Table 8). The only published evidence of decline for *R. cascadae* is from Lassen Volcanic National Park, which is at the southern end of the *R. cascadae* range (Fellers and Drost 1993). Repeated references have been made in the literature to possible declines in the Oregon Cascades (Blaustein and Wake 1990; Blaustein et al. 1994b; Fite et al. 1998), but results of these surveys remain unpublished. Thus, we conclude that *R. cascadae* tends to have breeding populations in ponds that have relatively high UV-B attenuation in Olympic National Park, but there is currently little evidence that recent increases in ambient UV-B have broadly affected amphibian populations.

A MONITORING DESIGN FOR STREAM AMPHIBIANS

Michael J. Adams

The inventory data we collected is useful for designing a long-term monitoring program at ONP. While the eventual design of any amphibian monitoring in ONP will require more input from park personnel, we think it is worthwhile here to design a monitoring program as an example of how these data can be used. Here, we address issues of power and sample size but do not discuss the sampling frame.

Design

There are four factors that comprise the design of a stream amphibian monitoring program: 1) the number of plots sampled within a stream; 2) the number of streams sampled in a season; 3) the number of times a steam is surveyed in a year; and 4) the time interval between stream surveys.

We determined the number of plots that need to be sampled within a stream based on a precision calculation independent of the other factors. The precision of a survey is the probability that the resulting density estimate ($\hat{\bar{X}}$) will be within ε(100)% of the true density ($\bar{X}$), (1 - α)% of the time (Skalski and Robson 1992). This can be expressed

$$P\left(\left|\frac{\hat{\bar{X}}-\bar{X}}{\bar{X}}\right|<\varepsilon\right)=1-\alpha .$$

Robson and Regier (1964) recommend the following precision levels: 1) α = 0.05 and ε = 0.50 for preliminary surveys and rough management work; 2) α = 0.05 and ε = 0.25 for accurate management work; and 3) α = 0.05 and ε = 0.10 for careful research and modeling. Because stream amphibian monitoring will be ongoing and little stake will be placed on any one survey, we chose precision of α = 0.05 and ε = 0.50.

To estimate the number of segments (=plots) that must be sampled in a stream to achieve the desired precision, I used the following formula:

$$k=\frac{1}{\left(\dfrac{\varepsilon(\bar{X})}{Z_{\frac{1-\alpha}{2}}s}\right)^2+\dfrac{1}{K}}$$

where k = the number of plots needed and K = the total number of plots possible.

We calculated the mean number of each species of stream amphibian per segment and their standard deviation within each 100-m reach (Appendix G). We then calculated the coefficient of variation (CV) for each species for each survey and calculated an average CV for each species. Average CV's for tailed frogs, Cope's giant salamanders, and Olympic torrent salamanders were 1.63, 1.79, and 1.95, respectively. The average count per segment for tailed frogs, Cope's giant salamanders, and Olympic torrent salamanders were 0.74, 0.17, and 0.19, respectively. Thus, to be conservative, we used a mean of 0.4 and a CV of 1.9 (s = 0.76) to calculate precision.

Using these numbers and the formula for k given above, we estimate that sampling 36 segments in each stream will give a density estimate that is within 50% of the true mean, 95% of the time. This estimate is based on sampling 1-m long segments as used in the stream inventory reported elsewhere in this report. We did not evaluate segment length.

We used the program MONITOR (freeware written by J. Gibbs, http://www.im.nbs.gov./powcase/powcase.html) to optimize the number of streams to sample, the number of surveys in a season, and the time interval between survey years. Monitor requires several input variables to estimate the power to detect a given trend using a given monitoring design. Foremost is the need for estimates of the initial mean and the standard deviation of counts for each plot. Because the means represent counts, we generated Poisson random distributions of initial counts using λ = 1/mean = 1/0.4 = 2.5 (we rounded the mean of the mean counts of each species from 0.3667 to 0.4).

We used our precision estimate to estimate the standard error (SE) of our mean counts. We specified that the difference between the true mean and our mean count would be $\pm\bar{X}\varepsilon$, 95% of the time. This is equivalent to a 95% confidence interval and

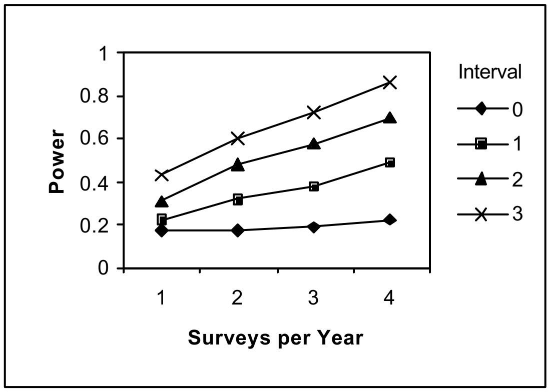

Figure 12. Power to detect a 5% annual decrease in abundance for 10 streams.

$$\overline{X}\varepsilon = Z_{\frac{1-\alpha}{2}}\left(\mathrm{SE}(\hat{\overline{X}})\right).$$

Substituting our values we get

$$0.4(0.5) = 1.96(\mathrm{SE}(\hat{\overline{X}}))$$

$$\mathrm{SE}(\hat{\overline{X}}) = 0.102$$

As s = SE√n, we estimate that repeated samples of 36 stream segments from an average stream will yield a standard deviation of 0.6 or, assuming a mean count of 0.4, a CV of 1.5.

The only other parameter estimate required by MONITOR is an estimate of the variability in temporal trends among streams. In other words, how much will individual streams differ in the temporal population trends they exhibit? I do not have an estimate for this parameter and use the moderate value of 0.01.

Using these estimates and specifying exponential trends (because population change is likely a multiplicative process), a significance level of 0.05, 2 tails, a constant of 1, decimal rounding, and 500 iterations, I explored the effects of the number of streams surveyed, surveys per year, and years between surveys on the power to detect a 5% annual trend after 4 sampling intervals.

Increasing the number of surveys per year and the number of years between years when surveys are conducted both increase the power to detect a 5% decrease in abundance after five survey years have been completed (Figure 12). However, multiple surveys per year are not worthwhile if surveys will be conducted every year. Increasing the number of streams monitored also increases power and sampling 20 streams, twice per year, every 4th year yields power of 0.71 (Figure 11). Sampling 30 streams, twice per year is probably the most that a 2-person crew could manage. This scenario gives power of 0.85 after four survey intervals when the interval is every 4th year.

A final option for increasing power is to decrease the CV associated with the mean number of individuals captured per segment. The CV could be lowered by sampling more segments in a stream and thereby increasing precision. However, a large number of segments would need to be surveyed. For example, 66 segments would need to be sampled to decrease the CV to 1.0. Moreover, decreasing the CV from 1.5 to 1.0 does little to increase power (Figure 13). In fact, I suggest that somewhat less than 36 segments (e.g. 25-30) could be sampled with little decrease in power.

A Minimum Plan

The analysis above allows me to make a conservative recommendation of a minimum plan to monitor stream amphibians in ONP. By conservative, I mean that power may be

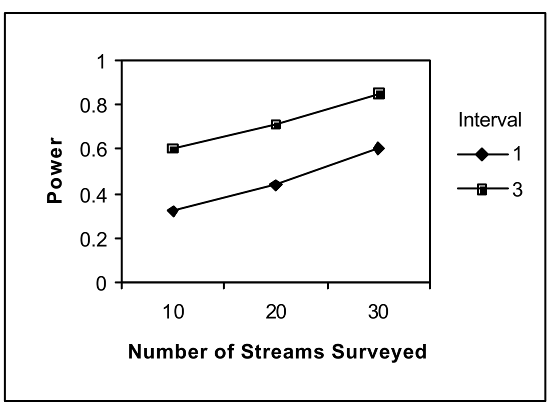

Figure 11. Power to detect a 5% annual decrease in abundance for a variable number of streams.

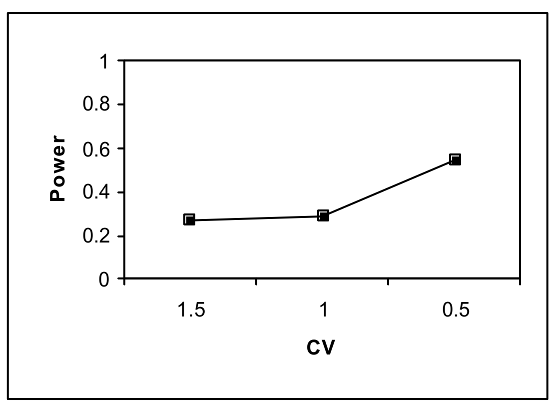

Figure 13. Power to detect a 3% annual decrease in abundance in relation to CV.

better than what we have estimated. For example, a drastically lower observed CV could increase power. Also, analytical tools like generalized linear modeling and weighted regression may improve power.

I recommend that 20 streams with known populations of amphibians be selected from no more than 4 major drainages. The number of drainages does not directly effect overall power to detect park-wide trends, but power to detect trends within drainages will be related to the number of streams surveyed in a drainage. Moreover, spreading the streams over many drainages could increase the variation among streams in any temporal trends which could lower power.

Streams should be surveyed following Bury and Major's (see Stream Techniques chapter) basic design of randomly selecting 1-m segments. Habitat variables collected are optional. The major change that I recommend for a monitoring program is that 36 rather than 10 segments be surveyed and that, on years when surveys occur, each stream be surveyed twice. Sampling should occur every 4th year (i.e., 3 non-survey years should occur between years with surveys). Thus, 20 streams should be chosen to be sampled twice every 4th year and 36 segments should be sampled every time the stream is sampled. I estimate that this design should detect a 5% annual decrease in abundance over a 16 year period (4 years of which had stream surveys) at least 71% of the time. Power to detect an increase in abundance will be greater and I suspect that actual overall power may be greater for the reasons I discussed above (e.g., lower CV, analytical methods).

Finally, I do not suggest that this is the only way a monitoring plan can be structured. A number of other features may need to be considered. For example, coverage could be increased with little increase in cost by using a rotational survey design (see Skalski 1990). Also, it may be desirable to design the monitoring program to detect trends within sub-regions of the park. This would require sampling more streams. Finally, our surveys only provide inference for stream reaches directly above trails. Ideally, a broader range of inference would be achieved by implementing a broader sampling frame.

ECOLOGY AND ANCILLARY STUDIES

Larval Life History of Tailed Frogs in Olympic and North Cascades National Parks

Michael J. Adams

Larval life history patterns can have important implications for population dynamics and can reveal differences in population status over time or space. Tailed frogs are an ancient lineage (Cannatella and Hillis 1993) that occurs throughout the Pacific Northwest of North America (Nussbaum et al. 1983). They range across environmental regimes from wet and mild in coastal sites (Bury 1968) to drier, colder conditions in the interior Rocky Mountains (Metter 1967; Daugherty and Sheldon 1982). Their tadpoles have long larval periods and require permanent, rocky streams that are cool and well oxygenated all year (Noble and Putnam 1931; de Vlaming and Bury 1970; Corn and Bury 1989). These features provide a unique combination for study of larval life-history and adaptation.

Age at metamorphosis in tailed frogs can be determined from size classes (using total length) and developmental stage (Metter 1967; Bury and Adams 1999). Tailed frogs generally have a 2 year larval period in coastal areas, 2-3 years in the Cascade Mountains, and 3 years in the Rocky Mountains (Metter 1967). However, a 1 year larval period occurs along the southern Oregon coast and in northern California (Wallace and Diller 1998; Bury and Adams 1999). Moreover, a 4 year larval period occurs in the Mount Baker region of the Cascade Mountains in northern Washington (Brown 1990). Thus, the larval period of tailed frogs shows considerable variation with environmental conditions.

Given the wide range of larval periods that tailed frogs exhibit, we queried the capture data from our stream surveys in Olympic National Park to characterize any samples of tailed frog larvae that were large enough for analysis. Also, we surveyed Happy Creek in North Cascades National Park to capture large samples of tailed frog tadpoles and determine the length of larval life. Our objective was to document examples of larval life history patterns in ONP and NOCA.

The main difficulty in determining the number of larval age classes from their size distribution is determining whether any metamorphs caught in mid-summer samples constitute a separate age class from the largest size class of larvae. This can be accomplished by comparing the hind-leg length (HLL) of the metamorphs to the HLL of the largest size class of larvae (Bury and Adams 1999). If metamorphs are a separate age class from other larvae, their HLLs should form a size class distinctly larger than that of the larvae.

Results

We obtained 3 samples of tadpoles and metamorphs from Happy Creek in North Cascades National Park (Figure 14). This creek crosses highway 20 just east of Ross Dam (elevation = 700 m). The June 1998

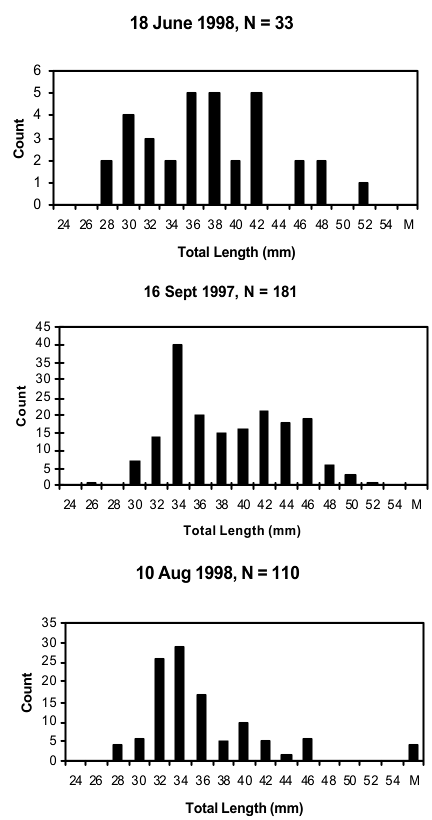

Figure 14. Size distribution of tailed frog larvae at Happy Creek in North Cascades National Park.

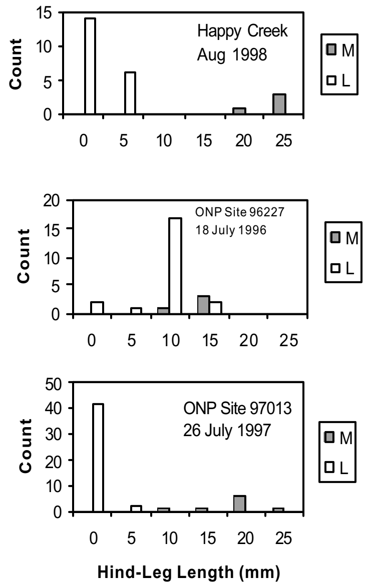

Figure 15. Size classes of tailed frogs based on HLL. M = metamorphs; L = larvae.

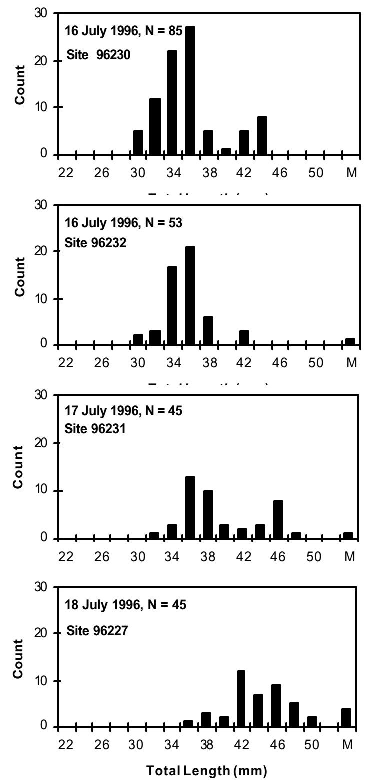

Figure 16. Size distribution of tailed frog tadpoles in 4 streams from the Lyre River drainage in Olympic National Park.

sample is small (N = 33) and is difficult to evaluate. The August 1998 sample shows two size classes of larvae plus metamorphs. Our analysis of HLL indicates that the metamorphs are an age class separate from the two larval age classes because metamorphs have distinctly longer hind legs (Figure 15). The September 1997 sample shows two size classes of larvae; we assume there was a third age class of metamorphs that had already left the stream.

We obtained 7 samples of tailed frog larvae that were sufficiently large for analysis in Olympic National Park. Four of these were fom the Lyre River drainage in the northwestern portion of the park (Figure 16). These all had two size classes of larvae. Metamorphs, when present, did not represent a separate age class based on HLL (e.g., Site 96227, Figure 15).

Three samples from other areas of the park also showed two size classes of larvae (Figure 17). A forth sample from Site 97013 had one size class of larvae plus metamorphs that had HLLs distinct from those of the larvae (Figure 15).

Discussion

Our evidence is consistent with other studies showing a 2 year larval period in Olympic National Park (Bury and Adams 1999). Given the pronounced environmental gradients in ONP it is surprising that none of the samples we obtained indicate any other pattern of larval development. For example, we might expect that colder areas would exhibit a 3 year larval period.

This lack of variability raises a question about the ability of tailed frogs to adapt to a changing climate. Tailed frog are able to cope with a wide range of climatic conditions rangewide, but the lack of variability within a region like ONP may suggest that this trait has become genetically fixed. More work is needed to determine the extent to with age at metamorphosis is a plastic trait that responds to environmental conditions.

In contrast to ONP, our samples from Happy Creek in North Cascades National Park suggest a 3 year larval period. This differs from Metter's (1967) finding of a two year larval period near the Nooksack River and differs from the 4 year larval period reported for a population near Mt. Baker (Brown 1990). However, Metter (1967) also reported a 3 year larval period near Stevens

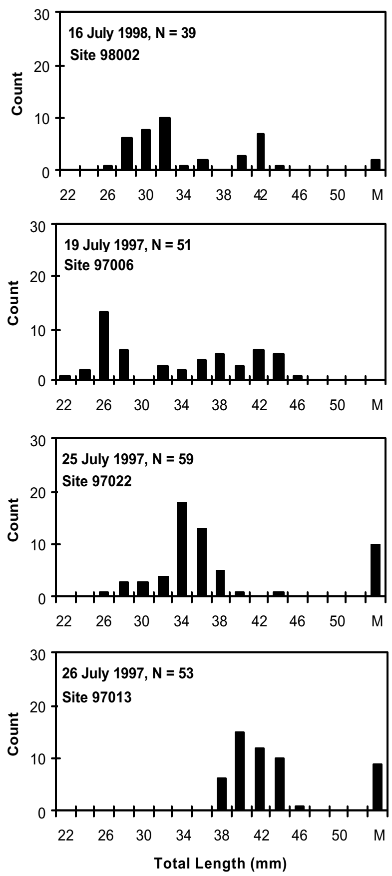

Figure 17. Size distributions of tailed frog larvae from streams in 3 drainages from Olympic National Park. Site 97006 is in the North Fork of the Quinalt, 97022 and 97013 are in the Bogachiel, and 98002 is from the Gray Wolf.

Pass to the south and the Nooksack River population was at a fairly low elevation (600 m). More samples are needed for North Cascades National Park to characterize the larval life history variation in this region.

All else being equal, a longer larval period will confer lower survival to first reproduction and thus, lower population growth rates. However, populations with longer larval periods might adjust to this in a number ways. For example, we could hypothesize the populations with a longer larval period will produce more eggs. We found some support for this in the relatively small clutch sizes of tailed frogs that we reported for ONP (see chapter on Tailed Frog Nests). Using our nest data and data from nests reported in the literature, we were able to demonstrate what appears to be a trend towards larger clutch sizes from inland populations.

Much work is needed to understand the life history strategy for any species and this task is all the more difficult for tailed frogs which are cryptic and often hard to find in high numbers. Moreover, their complex life cycles add an extra complication. However, further study of life history traits can reveal how tailed frog populations function and how they might respond to climate change.

Ranid Frog Genetic Differentiation Study in Olympic and North Cascades National Parks: Preliminary Results

Kirsten J. Monsen and Michael S. Blouin

Cascade Frogs in Olympic National Park

Amphibians have experienced population declines worldwide (Blaustein and Wake 1990), creating an increasing need for the management of these species. To effectively manage organisms, it is necessary to understand how genetically distinct different populations are from one another. *Rana cascadae* is a frog species endemic to the mountains of the Pacific Northwest. Over the last several decades, this species has experienced population declines in some parts of its range (Nussbaum et al. 1983; Fellers and Drost 1993).

To assess the amount of genetic differentiation present in populations of *R. cascadae*, we analyzed a 290 base pair fragment of the mitochondrial control region using the polymerase chain reaction, single stranded conformation polymorphism analysis, and DNA sequencing. We analyzed DNA samples from 12 populations throughout the species' range, including 77 adults from Clear Lake and surrounding ponds in the Seven Lakes Basin of Olympic National Park, Washington.

All animals we examined from the Olympic National Park shared the same genotype. This genotype was not found in any of the other populations sampled, suggesting the Olympic *Rana cascadae* compose a unique genetic group. This result is most likely due to the geographic separation of the Olympic populations from the rest of the species range, which extends through the Cascade Mountains of Washington, Oregon, and Northern California. To assess the prevalence of this genotype in other populations on the Olympic Peninsula, it will be necessary to perform the above analysis on a much finer scale. In the future, we hope to do this by sampling from several other populations across the Olympic peninsula.

Unidentified frogs in North Cascades

We performed the above analysis on 10 ranid frogs from the Big Beaver area in the Northern Cascades National Park to positively identify them to species. We had difficulty amplifying the control region, so another mitochondrial marker, the ND1 gene, was used in the analysis. All 10 animals from the Big Beaver population share the same ND1 pattern as *Rana luteiventris*. It is important to note however, mitochondrial DNA is maternally inherited, so these animals may be hybrids between female *Rana luteiventris* and males of another species. We plan to analyze these individuals with biparentally inherited nuclear markers to determine if they are pure *Rana luteiventris*.

Some Preliminary Population Data for the Columbia Spotted Frogs (*Rana lutieventris*) at Dagger Lake, North Cascades National Park

Michael J. Adams and Donald J. Major

The distribution of the spotted frog complex (Oregon spotted frog, *Rana pretiosa*; and Columbia spotted frog, *Rana lutieventris*; Green et al. 1997) is highly fragmented. This fragmentation appears natural and not the result of landscape modification by humans. However, there is concern over the conservation status of both species (McAllister et al. 1993; Green et al. 1997).

A cluster of both species of spotted frogs occurs in the North Cascades region of Washington State (Green et al. 1997). Dagger Lake, located in the eastern part of North Cascades National Park, is in this cluster and has a population of Columbia spotted frogs. Because of conservation problems with spotted frogs and a lack of basic information about their population parameters, we documented attributes of the population at this relatively undisturbed site.

Here, we describe a population estimate and an egg mass count for Columbia spotted frogs at Dagger Lake.

Population Estimate

We conducted a mark-recapture study of Dagger Lake spotted frogs in 1997. Four workers in groups of two searched the entire shoreline as well as associated wet meadows for spotted frogs. They did this on three consecutive days (23-25 August 1997). For each frog captured, they either marked it with a unique number or recorded the number it had been previously given, and then released it at the point of capture. Marking was accomplished by toe clipping (Table 12). Thumbs were not clipped.

A total of 168 captures were made of 141 unique frogs (Appendix F). We analyzed these captures using a macro created for the software GLIM (Francis et al. 1993). The name of the macro is "recap.glm". Using GLIM allowed us to test model assumptions directly in a generalized linear modeling format. It let us build the best model for estimating population size based on the data and the tests of assumptions. The disadvantage is that the macro does not provide an error estimate or confidence interval.

The macro requires the capture histories to be summarized in a standard format (Table 11). From this capture history, we estimated an adult population size of 306 frogs.

Table 12. Marking system for frogs viewed from above the frog. For example, if the first digit of the fore feet and the eighth digit of the hind feet are clipped, the number is 63. If, in addition, the seventh digit of the fore feet was also clipped, the number is 369. If two toes were clipped on one foot, the lower of the two possible numbers is read. For example, if the forth, ninth, and tenth digits of the hind feet are clipped, the number is 142 (not 241).

	Left					Right				
Digit:	1	2	3	4	5	6	7	8	9	10
Fore feet	60	70	80	90	not used	not used	9	8	7	6
Hind feet	10	20	30	40	50	5	4	3	2	1
2° *						500	400	300	200	100

* Secondary numbers are read when three toes are clipped.

Table 11. Summary of capture histories for spotted frogs at Dagger Lake. N is the number of frogs that had the capture history indicated (1 = captured; 0 = not captured).

N	Day 1	Day 2	Day 3
3	1	1	1
4	0	1	1
10	1	0	1
22	0	0	1
6	1	1	0
26	0	1	0
69	1	0	0

Egg Mass Count

On 19 June 1998, two workers surveyed Dagger Lake for spotted frog egg masses. They estimated a total of 77 egg masses (aggregation of masses prevented precise counting). All egg masses were located in shallow water and often protruded above the surface of the water. They were found between the designated campsite (mid-way of north side of lake) and the east end of the lake. An estimated 88% of the egg masses (68) were found in 4 large aggregations. These aggregations ranged in size from 3 egg masses (24X15cm) to approximately 48 egg masses (120X85cm). The workers attempted estimates of the number of eggs (to the nearest 50 eggs) contained within 6 isolated egg masses. These estimates averaged 283 eggs (350, 50, 350, 250, 450, and 250 eggs). Embryos ranges from approximately Gosner stage 12 to stage 22 (Gosner 1960).

Nesting Ecology of Tailed Frogs (*Ascaphus truei*) in Coastal Washington

R. Bruce Bury, Kim I. Mike, Dean Rofkar, and Patrick Loafman

Tailed frogs (*Ascaphus truei*) are primitive yet highly specialized amphibians, and are considered by some to be a sister group to other anurans (Ford and Cannatella 1993; Jamieson et al. 1993). The species ranges from British Columbia and western Montana south to northern California and from sea level to 2100 m (Nussbaum et al. 1983; Leonard et al. 1993). The female deposits eggs in mid-summer and attaches eggs to the undersides of rocky substrate in cold, fast-flowing streams that are permanent. The eggs of this primitive amphibian are the largest of any North American frog, and are slow to develop averaging 6 weeks to hatching (Brown 1975; Brown 1989). Further, the hatchlings may remain in the nest area for several months. Most larvae metamorphose after 2-3 yr (Metter 1964; Metter 1967), but may take up to 4 yr in high elevation, northern locales (Brown 1990) or only 1 yr in coastal areas from central Oregon to northern California (Wallace and Diller 1998; Bury and Adams 1999).

About a dozen nests of this species have been found in the wild (Table 13), including 5 nests from coastal or Coast Range areas. However, two nests reported for the Olympic Peninsula, Washington (Gaige 1920) lacked counts of the egg number. Adams (1993) found two nests (one with countable eggs) and reports counts from another nest from coastal Oregon.

In general, *Ascaphus* has small clutches of 45-60 eggs (Brown 1990). Metter (1967) counted ovarian eggs in 15 populations of *Ascaphus* and stated that there was considerable variation in egg numbers ($\bar{x}$ = 44.0–74.6) between populations but there was no notable geographic pattern. There is some disparity in the literature regarding clutch sizes and geographic variation in egg numbers. Our objectives were to describe the nesting ecology of this species and to quantify habitat features of nesting. We focused surveys on coastal populations where there are few prior records and, in turn, this allows a better comparison of nesting features across its range in the Pacific Northwest.

Materials and Methods

In the summers 1995-1998, we conducted surveys to determine distribution

Table 13. Reports of *Ascaphus* nests or eggs, excluding a few communal nests. Space (-) indicates that the author did not provide counts of eggs or a mean value.

Geographic Location Method	N	mean	N (range)	Regerences
Coastal/Coast Ranges				
Wild nests	2	-	-	Gaige (1920)
	2	-	60	Adams (1993)
	1	-	38	P.S. Corn in Adams (1993)
	5	57.8	(40-96)	This study.
Induced ovulation	5	36.6	(28-47)	Noble and Putnam (1931)
Dissection	2	42	(35-49)	Gaige (1920)
	7	49.3	(39-61)	Metter (1967)
Cascade Mountains				
Wild	2	-	-	Brown (1975)
Induced ovulation	22	58.8	(37-82)	Brown (1975)
Dissection	33	56.0*	(41-85)	Metter (1967)
	16	57.9*	(44-98)	Metter (1967)
Inland/Rockies				
Wild	2	75	(64-86)	Franz (1970)
	“several”	-	(40-70)	Metter (1964)
Dissection	20	68	(50-85)	Metter (1964)
	58	63.5*	(33-97)	Metter (1967)

* Recalculated from mean value and number of females at each site.

and abundance of stream-breeding amphibians in Olympic National Park (ONP), located on the Olympic Peninsula in northwestern Washington State. There are 13 major drainages in ONP radiating outward from the Olympic Mountains situated in the center of the peninsula. Peaks rise up to 2,865 m elevation and the terrain is steep. To gain access to ONP, we used the existing network of trails and a few roads that mostly were parallel to the main rivers or large tributaries. First, we hiked (or occasionally drove) along the transects and recorded all streams with flowing water that intersected our path. Then, we randomly selected one-third to one-half of these streams for intensive search.

We sampled 168 streams based on a new method (modified from Bury and Corn, 1991): 10 1-m long bands randomly chosen and searched over a 100-m section of water. We located surveys 30 m above trail and road crossings. We also revisited some streams in subsequent years and the total length of waters searched was 1,714 m. In each band (1-m long), we fist did a visual scan and hand-captured any observed amphibians but most sampling consisted of turning over rocks and woody debris, and collecting amphibians that drifted downstream into dipnets.

Results

We found 6 nests of the tailed frog in four ONP watersheds (Table 14). This represents an occurrence rate of only 0.35% of the 1-m belts and 3.6% of streams, or 1 nest/286 m and l nest/28 streams. However, our preliminary results of field surveys indicate that *Ascaphus* occurred in 60% of the selected streams. Thus, for those waters with known *Ascaphus* populations (n = 94), we found 1 nest/171 m or 1 nest/16 streams.

We discovered 3 of the nests on the north side of the Park in 1996: two in small tributaries of the North Fork Soleduck River and one in a tributary of the Elwha River. The other 3 nests were found on the drier east side of the Park in summer 1998: one in the Skokomish drainage and two nests 7 m apart in the same creek flowing into the Dosewallips River.

The two Dosewallips nests appeared to be deposited at different times because they differed in embryo sizes (15 and 18 mm). All nests had eggs congealed into a mass, except the nest found in the Skokomish basin that had 96 newly deposited eggs still in a rosary-like string and attached at one end to the underside of a rock (the loose end flowed downstream in the dipnet when the rock was turned). Also, a female was found in the dipnet and may have been recently completed depositing eggs.

The numbers of eggs for 4 ONP masses were low (x = 48.3, range 40–55), but one single nest in the Skokomish drainage had a high count (N = 96 eggs). We also found one large nest (n = 182 eggs) in a tributary off the North Fork Soleduck River, and we consider it to be communal nests and do not include them in our counts of single nests (Table 14).

Discussion

Our data and other evidence (see Table 13) indicate a possible geographic trend in clutch size. Like other coastal populations, 5 ONP nests had few eggs (x = 57.8, range 40–96) compared to inland populations (Table 13). The nest with 96

Table 14. Location and habitat data for tailed frog nests from Olympic National Park, Washington. Abbreviations for watersheds: NFS = N. Fork Soleduck; ELW = Elwha; SKO = Skokomish; DOS = Dosewallips

Watershed	NFS	NFS	ELW	SKO	DOS	DOS
Date Found	31 Jul 1996	6 Aug 1996	15 Aug 1996	8 July 1998	4 Aug 1998	4 Aug 1998
No. Eggs	55	182	52	96	40	46
Rock Size (cm)	19X15X8.5	100X50X20	55X45	15X14X5	11X9X4.5	35X19X14
Environment	Riffle	Pool	Pool	Riffle	Pool	Pool
Water Temp. C	11.0	8.5	11.0	10.0	7.0	7.0
Elevation (m)	648	640	579	1122	610	610
Gradient (%)	8	25	16	17	21	21

eggs is a record high for a coastal female. On the east side of the Olympic Peninsula, Washington, Gaige (1920) reported finding 35 and 49 eggs inside two females while Noble and Putnam (1931) induced ovulation in 5 females and the mean was low ($\bar{x}$ = 36.6). Metter (1967) dissected 7 females from Mary's Peak in the Oregon Coast Range and mean was moderately low ($\bar{x}$ = 49.3). Adams (1993) reported counts for 2 of 3 nests from coastal Oregon streams: 38 eggs (P.S. Corn, pers. obs.), and 60 (27 well-developed eggs plus 33 small hatchlings in one nest). There were also 18 older hatchlings found in the same pool but these were dispersed and able to swim; these are not included as a count because they likely represent an incomplete clutch.

Inland populations from the Cascade Mountains had similar counts of eggs. Metter (1967) and Brown (1975) obtained eggs from a large sample (n = 71 females) and mean values of three groups were 56.0-58.8 (Table 13). Overall, the Cascade samples appear to have 10-20 more eggs per clutch than the records from coastal areas. Wernz and Storm (1969) found 2-83 eggs in 5 clutches, but these were from mixed sites (Oregon Coast Range and Cascades) and we do not include them in our summary.

Further inland, populations from eastern Washington to western Montana in the Rocky Mountains have higher counts (Table 13). Franz (1970) reported two large nests from the wild in western Montana. Metter (1964) stated that 20 ripe females from two inland areas (eastern Washington, northern Idaho) averaged 68 eggs per female. Metter (1967) dissected animals from 7 inland sites and values were again high. Overall, inland nests and clutches appear to consistently have about 10 more eggs than those from coastal and Cascade Mountain sites.

Metter (1964) suggested that it is possible that *Ascaphus* oviposit every year in coastal areas and every other year inland. If true, *Ascaphus* would have yearly clutches of relatively small numbers in coastal populations compared to biennual nesting with larger clutches for inland areas. The frequency of nesting (yearly, biennially) remains poorly defined in *Ascaphus* and additional study is needed to increase the sample of nests or counts of ripe eggs, especially from females in coastal regions.

Induced ovulation of eggs may increase data from coastal areas because this method yielded relatively large samples for number of eggs from inland populations (see Metter 1967). Moreover, this technique is harmless to the female and, thus, is preferred where there are small or protected populations. Numbers of eggs from dissection of females or induced ovulation likely is more accurate than counts in nests because, under natural conditions, eggs are subject to physical loss. *Ascaphus* occur in fast-flowing streams where eggs can be washed away by the currents. Also, eggs are likely eaten by predators such as giant salamanders (genus *Dicamptodon*), which often co-exisit with *Ascaphus* and are known to feed on larval *Ascaphus* (Metter 1963).

Two instances of communal nesting are now known in *Ascaphus*. Brown (1975) found 123 eggs and 20 females under one rock near Mount Baker, Washington. We found one nest with high counts of eggs (N = 182). This likely could include eggs from as few as two females or as many as 5-6 based on reported clutch sizes. Currently, we lack information on whether females return to these communal areas in subsequent years or why several females deposit eggs in a specific parts of streams.

The habitat of *Ascaphus* is often described as being in the upper headwaters of drainages. However, nests we found (except for the Skokomish record) were in the lower portions of streams near where they feed into main lowland rivers. All *Ascaphus* nests to date have been found under large rocks, presumably those large enough not to be moved by the current. In Olympic National Park, we found 4 nests in pools of streams and the other two were in riffles. Most nests were under large rocks but these varied widely from surface lengths of 11 x 9 cm to 100 x 50 cm. Average rock length was 39.2 cm; width, 25.3 cm; and height, 10.4 cm. In general, the nests were not under the largest rock or boulder in streams. However, we do not dislodge the largest rocky substrata because we were surveying in a National Park, a protected habitat.

Brown (1975) reported that eggs of tailed frogs require a low thermal range (5-

18.5 C). We recorded 7-11 C in water near nests, which are within the range for normal development. Egg deposition reportedly occurs in July rangewide (Metter 1967; Brown 1975; Adams 1993). Our data supports this pattern as nests were found July 31-August 15.

Compared to other anurans, egg masses of *Ascaphus* remain scarce. Low detection of nests may be due to several factors, including: (1) placement of eggs under large rocks and boulders; (2) occasional communal nesting (i.e., concentration of eggs in a few sites); and (3) lack of extensive searches (i.e., limited areas can be searched due to rocky substrates). Although few nests are known from the wild, our ONP surveys doubles both the number of tailed frog nests known west of the Cascade Mountains and the number of nests with counts of eggs rangewide.

ONP is one of the largest undisturbed areas in the Pacific Northwest and lacks negative influence of disturbances such as timber harvest (see Corn and Bury 1989; Diller and Wallace 1999) or siltation from large road construction (Welsh and Ollivier 1998). Still, we rarely encountered *Ascaphus* nests even with many surveys in this relatively pristine habitat. Although there were some similarities in features of nests, all habitat characteristics we measured were variable among nest sites. Thus, further research is needed to better define the nesting and habitat requirements of *Ascaphus*. In particular, effective management and protection for this ancient lineage of anurans will be difficult without a better understanding of its basic ecology.

CONCLUSION: STATUS OF AMPHIBIANS IN OLYMPIC AND NORTH CASCADES NATIONAL PARKS

R. Bruce Bury, Michael J. Adams, Reed S. Glesne, and Ronald E. Holmes

There is now concern for amphibian declines worldwide (Blaustein and Wake 1990; Wake 1991) and in the United States (Bury et al. 1980). However, not all species are declining (Corn 1994; Bury 1999) and the reasons for declines are not always readily apparent (Pechmann et al. 1991; Corn 1994). We need to know the status of amphibians in our National Parks so that we can gauge the extent of the declining amphibian problem and, hopefully, take preemptive or corrective measures if losses are detected.

Determining the status of a species is a daunting task in large National Parks and we are often challenged to even define what we mean by “status". At one end of the spectrum, the status of a species may simply be summarized by an assessment of its current distribution compared to prior occurrence. More often, we also wish to document any population trends (e.g., survival and reproductive rates over time). However, such information is hard to obtain and these population parameters may not tell the whole story of “status” unless we can put them into some sort of spatial and temporal context. For example, detecting a 5% annual decrease in abundance over a five year period may give little cause for concern if population trends fluctuate on a scale of decades. Moreover, a decline or extinction in a few populations is not cause for concern if other new populations have appeared.

Thus, we are frequently left to rely on a large degree of speculation and expert opinion when we seek to determine the status of a species or group of species. The amphibian surveys in Olympic (OLYM) and North Cascades (NOCA) National Parks in the past four years have provided a large quantity of data pertaining to the distribution and abundance of amphibians. However, they provide little data on population parameters.

There are some historic amphibian records (especially for OLYM), but these are of little value for comparison because of imprecise locality information and a lack of a well documented, formal survey in the past. Amphibian declines have been demonstrated in Rocky Mountain and Sequoia National Parks, and Lassen Volcano National Monument by re-surveying known amphibian localities and nearby (new) habitats lacking previously documented surveys. With such surveys, declines are indicated when many historic localities now lack the species in question and new surveys do not reveal substantial numbers of new records. There is still a matter of degree involved in assessing status from such efforts and we can really only be certain of declines when the patterns are extreme (i.e., few or no populations persist at historic localities and few or no new populations are found). Such is the case for western toads in the Rocky Mountains, mountain yellow-legged frog and Yosemite toad in the Sierra Nevada, and the Cascade frog at the southern tip of its range (Fellers and Drost 1993; Corn 1994).

For Olympic and North Cascade National Parks, we are only able to compare what we have learned about current amphibian distribution patterns to what little we know about historic distribution patterns. Most of our expectations are based on knowledge of the distribution patterns and natural history of these species. Although we can point to a few potential problems (e.g., impact of introduced fishes), there is little cause for immediate concern over widespread amphibian losses in the two parks. However, there is also little direct evidence to assess amphibian status. Introduced fishes may be the most serious threat in lakes and ponds and are currently being assessed in NOCA and other areas. Changes induced by air pollution and global climate change will be increasing threats in the future, and these also need closer scrutiny in our National Parks to recognize and prevent effects early on. Lastly, losses of amphibians may occur rapidly and it is important to have baseline data sets to monitor changes in populations.

That said, the thorough documentation of amphibian distribution patterns is an important first step and provides much more information than is generally available for assessing status. Here, we summarize and discuss how the patterns we documented compare to our expectations based on knowledge of amphibian natural histories and distributions. In 1996-98, we surveyed 90 ponds/lakes, 75 streams, and 14 seeps in NOCA (n = 179 sites, Table 15) and 199 ponds/lakes, 168 streams and 244 seeps in OLYM (n = 611 sites, Table 16). Field surveys resulted in over 635 new locality records of amphibians in OLYM and 132 in NOCA.

Species Accounts

Pond-Breeding Amphibians

Long-Toed Salamander, *Ambystoma macrodactulym*

There is a negative correlation of this small-sized salamander with abundance of introduced fishes in Washington Cascade lakes (Tyler et al. 1998a), but the salamander appears to be fairly widespread in the region. There appears to be many fishless habitats (e.g., small, shallow ponds) in OLYM as well as lakes and ponds with low fish density (in NOCA), where *A. macrodactulym* continue to persist.

Northwestern Salamander, *Ambystoma gracile*

This species has reduced survivorship in the presence of introduced trout (Tyler et al. 1998b). However, it appears to be less impacted by fish than is *A. macrodactulym* (G. Larson, pers. comm.) for two possible reasons. Northwestern salamanders obtain much larger sizes than Long-toed salamanders, which in itself may provide some protection. Next, *A. gracile*—especially the larger larvae and paedomorphs—may coexist with fishes because the salamanders have skin toxins that may make them unpalatable to fish. In OLYM, *A. gracile* is widespread and, at present, there is little cause for concern over its status. The salamander was in some basins in NOCA, but appear to be absent at higher elevations and only on west side of the Cascade crest. This area approaches the northern limit of the range of the species.

Cascade Frog, *Rana cascadae*

We found fewer or no *R. cascadae* in waters with introduced salmonid fishes. Many of these were large, permanent waters. It is unknown if Cascade frogs naturally avoid large waters because now almost all larger waters have introduced fishes. Fish are no longer planted in OLYM, but there are many self-reproducing populations remaining. We found many *R. cascadae* breeding in small, temporary ponds. *R. cascadae* in OLYM were present in most montane ponds and lakes (57.3% of 199 sites), and with signs of breeding (egg masses or tadpoles) at many sites (30.2%). Overall, *R. cascadae* is doing well in OLYM. Only 3 sites had *R. cascadae* in NOCA, but this park is at the edge of the frog's range.

Blaustein et al. (1994a) suggested that there was a negative effect on *R. cascadae* of UV-B exposure in the Oregon Cascade Mountains and that this species was declining. Our data show that *R. cascadae* were more common in ponds that had high dissolved organic carbon and thus, were relatively protected from UV-B. However, we found that *R. cascadae* is the most common pond-breeding amphibian in OLYM. We conclude that there is evidence that UV-B can be damaging to *R. cascadae* and effect distribution patterns, but see no evidence that UV-B has caused declines in OLYM.

Western Toad, *Bufo boreas*

This species was more rare than we expected in montane ponds. The toad occupies high elevations elsewhere in its range across western North America, but may be a different species in the Rocky Mountains where few populations remain (Corn 1994). The western toad was found at several low elevation sites on the west side of ONP and further surveys are needed in these lowland areas. UV-B effects may impact populations at high elevations based on studies in the Oregon Cascade Mountains (Blaustein et al. 1994a), but not in the Rocky Mountains (Corn 1998). In NOCA the western toad is locally abundant in valley bottoms of Stehekin R., Big Beaver Ck., and lower Skagit River (125 – 750 m elev), with a few smaller populations at higher (1608 – 1871 m) elevations, on both sides of the crest.

Other Pond-Breeding Species

In OLYM, we found or observed rough-skinned newts at 7 sites; Pacific treefrogs, 7; and red-legged frogs, 6. All these species were infrequent in montane ponds and lakes that we searched. Newts and red-legged frogs appear to prefer lower elevation habitats in OLYM. Newts and treefrogs were occasionally found up to mid-elevations but rare at high elevations. Pacific treefrogs are a common species throughout the region, and may be abundant at higher elevations in other montane areas. Their low numbers at OLYM and NOCA may be related to their southern origins (i.e., treefrogs as a group are mostly a tropical or subtropical group). The northern latitude and elevated location of most of our surveys may be at the margin of the species' range or thermal tolerance.

In NOCA, there were also few Pacific treefrogs (12 sites), red-legged frogs (4), and newts (4). Red-legged frogs are abundant at lower Skagit River locations. The Spotted frog, *Rana luteiventris*, was moderately common (25.5%) and widespread (23 sites) in 90 ponds/lakes searched. *Rana luteiventris* is not known to have ever occurred in OLYM.

Stream-Breeding Amphibians

Cope's Giant Salamander, *Dicamptodon copei*

This species is only found in western Washington and not in NOCA. It was fairly common in most streams in ONP (35.1% of 168 sites) but infrequent in seeps (7.2% of 235 sites). Surprisingly, the species was not found in any waters in the northeast side of park. If this corner of OLYM is excluded from total counts, *D. copei* occurred more frequently (53.2% of 111 stream and 10.0% of 170 seeps). This distribution correlates with the southwest to northeast environmental gradient (wet to dry), but are analysis suggests that this gradient may not be solely responsible for the observed pattern. We suggest further study and active monitoring of this species. A few of the closely related Pacific giant salamander (*D. tenebrosus*) were found in westside locations in NOCA.

Tailed Frog, Ascaphus truei

There is some concern for the status of this endemic family of frogs, especially related to losses in areas outside of parks where there is intensive timber harvest. Tailed frogs were common: 57.7% of 168 streams at ONP and 49.3% of 75 streams at NOCA. Some occurred in seeps: 9.8% of 235 sites in OLYM and 7.1% of 14 in NOCA. We found *A. truei* at 97 streams and 23 seeps in ONP (n = 120 new localities), and 24 streams and 1 seep in NOCA (n = 25 new sites). We feel these numbers give no cause for concern in the parks.

Olympic Torrent Salamander, *Rhyacotriton olympicus*

Its northern range ends in the southern Washington Cascades, so the species is not found in NOCA. Timber harvest impacts the species through elevated water temperatures and siltation of stream substrate (Corn and Bury 1989). Inside the protected boundaries of OLYM, the salamander appears widespread with 178 new locality records. We found the salamander at 40.5% of the 168 streams and 46.8% of the 235 seeps. This pattern fits the ecology of the species as they tend to occur in shallow splash zones and seeps along streams. Few locations were found on the east side of the park, where conditions are drier and warmer than on the west side.

Van Dyke's Salamander, *Plethodon vandykei*

Breeds in seeps. The salamander has a spotty distribution throughout its range (Wilson and Larsen 1999). We found only 4 sites in OLYM. NOCA is outside the known range of this species.

Terrestrial Salamanders

Red-backed salamander (*Plethodon vehiculum*) is a species associated with uplands and talus slopes. We found them along 18 streams and 12 seeps in OLYM. Only one *P. vehiculum* was found in NOCA. Ensatina (*Ensatina eschscholtzii*) salamanders were caught in pitfall traps in lower elevation westside locations in NOCA (Big Beaver and lower Skagit). Ensatina was not found at high elevations or eastside. Additional surveying in terrestrial habitat is needed to asses the status of terrestrial species locally.

Conclusion

Currently, most species of amphibians in OLYM and NOCA appear to be stable or showing no signs of major distribution changes. This is encouraging news as other reports suggest marked declines of amphibians in the Rocky Mountains, Sierra

Nevada and Oregon Cascades. Why the northern parks have relatively "healthy" populations is unclear at this time. However, we should not let our guard down as rapid or catastrophic losses in amphibians have occurred in other parts of the world. Both OLYM and NOCA can also serve as sounding boards to better compare results from other regions (e.g., contaminant levels in the Sierra Nevada). The rarity of western toads at higher elevations, the unexpected distribution pattern of Cope's giant salamander, the isolated nature of spotted frog populations, and the rarity of long-toed salamanders and Cascade frogs with introduced fish all give cause for concern.

We have several recommendations. First, amphibians should be a component of any long-term monitoring in the northwestern National Parks. Their indicator status, links to multiple terrestrial and aquatic habitats, and worldwide evidence of sudden catastrophic declines justifies their inclusion.

Second, we believe there is ample justification for fish removal from some lakes in the parks. We know that fish cause dramatic changes in aquatic systems that are not consistent with preservation goals (Leavitt et al. 1994; Meijer et al. 1994; Wellborn 1994; Vanni et al. 1997; Harig and Bain 1998; Liss et al. 1998) and evidence is strong and growing that introduced fish have negative effects on amphibian populations (Kiesecker and Blaustein 1998; Tyler et al. 1998a; Tyler et al. 1998b; Adams et al. 1999; Adams 2000). In the northwestern national parks, small fishless ponds appear to compensate for any negative effects of fish in larger waters, but we don't know how important large waters are over long time periods. Lakes may be essential for the persistence of some species during periods of drought when smaller ponds have insufficient duration for amphibian reproduction. It seems prudent to assure that some larger fishless habitats are dispersed throughout the park. Ongoing efforts in Mount Rainier and Sequoia National Parks have demonstrated the feasibility of fish removal using gill nets (Knapp and Matthews 1998). Moreover, amphibians are already showing signs of increase in lakes where fish have been removed relative to control lakes. By only removing fish from a network of lakes, the needs of aquatic organisms and the desire for backcountry fishing opportunities can be balanced.

Finally, we suggest that western toads, Cope's giant salamander, and Columbia spotted frog all would benefit from further investigation into the factors affecting their distribution and abundance. The patterns we documented for western toads and Cope's giant salamander could both be indications of decline. Our lack of historic data to compare to precludes solid interpretation, but our current understanding of their biology gives cause for concern. In the case of Columbia spotted frog, we are not concerned that they are declining, although this species appears to be declining in parts of its range, but we feel that its fragmented distribution renders it vulnerable to perturbations.

Table 15. Amphibian detections in North Cascades National Park, 1996-98. Data are number of sites where each species was found with the number of sites where evidence of breeding was found in parentheses. Evidence of breeding is presence of eggs, larvae, or paedomorphs.

Drainage	Surveys	ASTR	RALU	HYRE	BUBO	RACA	RAAU	AMMA	AMGR	TAGR	ENES	DITE	PLVE
Big Beaver Ck.	27 Streams	14 (11)											
Big Beaver Ck.	22 Ponds		7 (4)	2 (2)	1 (1)			1 (1)	13 (13)	3 (1)			
Big Beaver Ck.	7 Seeps	1 (1)	1 (1)						1 (1)				
Big Beaver Ck.*	50 Pitfall traps		9 (2)	6 (6)	24 (24)			10 (5)	3	16	9 (0)		
Bridge Ck.	37 Streams	13 (10)				1 (0)							
Bridge Ck.	17 Ponds	1 (0)	6 (3)	2 (2)	2 (0)	2 (1)		7 (7)					
Bridge Ck.	7 Seeps							1 (1)					
Thunder Ck.	11 Streams	10 (10)											
Thunder Ck.	10 Ponds			1 (1)				1 (1)					
Lower Skagit R.	4 Ponds			1 (1)			1 (1)	1 (1)	1 (1)	1 (1)			
Lower Skagit R.*	incidental				1 (1)		1 (1)						1 (0)
Lower Skagit R.*	75 Pitfall traps						3 (0)				3 (0)		
Skymo Ck.	6 Ponds				3 (3)			3 (3)					
Little Beaver Ck.	13 Ponds							2 (2)					
Noisy Ck.	7 Ponds												
Cascade R.	7 Ponds							2 (2)					
Newhalem Ck.*	incidental											2 (0)	
Chilliwack River*	3 Ponds			1				2 (2)					
Stehekin Valley*	Pitfall traps		1	3	5	3		3					
Tyler AMMA study*	54 Ponds							25(25)					

* Not part of NRPP Amphibian inventory, collected in course of other project effort

ASTR = *Ascaphus truei*, tailed-frog
RALU = *Rana luteiventris*, Columbian spotted frog
HYRE = *Hyla (Pseudacris) regilla*, Pacific treefrog
BUBO = *Bufo boreas*, Western toad
RACA = *Rana cascadae*, Cascades frog
RAAU = *Rana aurora*, red-legged frog
AMMA = *Ambystoma macrodactylum*, long-toed salamander
AMGR = *Ambystome gracile*, Northwestern salamander
TAGR = *Taricha granulosa*, rough-skinned newt
ENES = *Ensatina eschscholtzii*, Ensatina
DITE = *Dicamptodon tenebrosus*, Pacific giant salamander
PLVE = *Plethodon vehiculum*, Western red-backed salamander

Table 16. Amphibian detections in Olympic National Park, 1996-98. Data are number of sites where each species was found with the number of sites where evidence of breeding was found in parentheses. Evidence of breeding is presence of eggs, larvae, or paedomorphs.

Drainage	Surveys	RACA	AMMA	TAGR	HYRE	BUBO	ASTR	AMGR	AMSP	RAAU	DICO	PLVA	PLVE	RHOL
Bogachiel	31 Streams						13 (12)				17 (16)	1 (1)	16 (16)	
Bogachiel	58 Seeps						1 (1)				3 (3)	2 (0)	4 (0)	34 (34)
Cameron	14 Seeps						4 (3)							
Dosewallips	9 Streams						7 (7)							1 (1)
East Fork Quinault	7Streams						3 (3)				4 (4)			5 (5)
East Fork Quinault	22 Seeps						4 (4)				7 (7)		3 (0)	9 (9)
Elwha	28 Streams						20 (20)						1 (0)	18 (18)
Elwha	47 Seeps						5 (3)						3 (0)	24 (24)
Gray Wolf	16 Ponds	14 (8)	4 (3)						6 (6)					
Gray Wolf	9 Streams						7 (7)							
Hamma Hamma	18 Ponds	14 (5)	4 (4)		1 (0)			4 (4)	10 (10)					
Hoh	6 Ponds				1 (1)	3 (2)				2 (0)				
Hoh	9 Streams						4 (4)				2 (2)			2 (1)
Hoh	9 Seeps	1 (0)					1 (1)				1 (1)			5 (5)
Lake Quinault	11 Streams						4 (4)				7 (6)			3 (3)
Lake Quinault	9 Seeps										3 (3)			4 (4)
Lyre	5 Streams						4 (4)							4 (4)
Lyre	4 Seeps						1 (1)						1 (0)	2 (2)
Morse	6 Streams						4 (4)							3 (3)
NF Quinalt	2 Ponds	1 (1)			1 (1)	1 (0)		1 (1)						
NF Quinalt	15 Streams						9 (6)				7 (7)	1 (0)		9 (9)
NF Quinalt	34 Seeps						2 (0)				2 (2)			17 (16)
North Fork Soleduck	8 Streams						7 (7)				7 (7)			8 (7)
North Fork Soleduck	9 Seeps						2 (1)			1 (0)				3 (2)
Queets	18 Ponds	8 (4)		2 (0)	2 (2)	2 (1)		6 (6)	5 (4)	2 (0)				
Queets	5 Streams					1 (0)	2 (2)				3 (3)			3 (3)
Queets	8 Seeps					1 (0)	2 (2)				1 (1)			8 (8)
Quillayute	1 Pond							1 (1)		1 (1)				
Skokomish	7 Ponds	3 (1)		1 (0)					1 (1)					
Skokomish	7 Streams						2 (1)				2 (2)		1 (0)	3 (3)
Skokomish	13 Seeps												1 (0)	3 (2)
Soleduck	131 Ponds	73 (41)	34 (27)	4 (0)	2 (0)	5 (5)	1 (0)	27 (25)	46 (45)	0 (0)	1 (1)			
Soleduck	18 Streams						11 (7)				5 (5)			9 (8)
Soleduck	8 Seeps						1 (1)							1 (1)

HYRE = *Hyla (Pseudacris) regilla*, Pacific treefrog
BUBO = *Bufo boreas*, western toad
RACA = *Rana cascadae*, Cascades frog
RAAU = *Rana aurora*, red-legged frog
ASTR = *Ascaphus truei*, tailed frog
AMMA = *Ambystoma macrodactylum*, long-toed salamander
AMGR = *Ambystome gracile*, northwestern salamander
TAGR = *Taricha granulosa*, rough-skinned newt
ENES = *Ensatina eschscholtzii*, Ensatina
DICO = *Dicamptodon copei*, Cope's giant salamander
RHOL = *Rhyacotriton olympicus*, Olympic torrent salamander
PLVE = *Plethodon vehiculum*, western red-backed salamander
PLVA = *Plethodon vandykei*, Van Dyke's salamander

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APPENDIX A: A GENERAL GUIDE TO THE AMPHIBIANS OF OLYMPIC NATIONAL PARK: FOR USE BY PARK INTERPRETIVE STAFF

Michael J. Adams, Shannon Claeson, and R. Bruce Bury

Amphibians

The name amphibian, meaning "double life", refers to the habits of most amphibians who spend part of their life in water and part on land. About 360 million years ago, amphibians evolved from fishes and were the first vertebrates adapted to life on land. Today there are three types of amphibians; salamanders, frogs and toads, and caecilians. Salamanders and frogs can be found here, while caecilians are found in tropical regions. Thirteen species of amphibian occur in Olympic National Park (ONP) (Table 17).

Frogs and Toads

Reproduction generally begins in the spring, or summer at high elevations, with males and females congregating in water sources. Nearly all frogs and toads fertilize their eggs externally, like fish. The tailed-frog is one of the few exceptions. Adult males have a protruding cloaca (the misnamed "tail") which is used to deposit sperm directly into the female's oviducts, where it is stored for ten months before fertilization of eggs in the following summer. Depending on the species, anuran eggs hatch in 3 to 8 weeks. Most tadpoles are herbivorous, feeding mainly upon green algae and bacteria. Tailed frog tadpoles have a round, sucker-like mouth that they use to hold on to rocks in flowing water while feeding on algae. Most tadpoles live in the water 2-3 months (tailed frogs 2 years), depending on the species. During the winter, adults bury themselves beneath logs, soil, or muddy pond bottoms and become inactive (not equivalent to true mammal hibernation).

Other than the tailed frog, all of ONP's frogs have tadpoles that reach metamorphosis after a few months. Only tailed frogs are known to overwinter as tadpoles. This means that the other three species of anuran must have tadpoles that develop very rapidly so that they can transform prior to the onset of winter. This is especially important at higher elevations where the growing season is only a few months at best.

Predators of eggs and tadpoles include aquatic insects, fish, snakes, mammals, birds, and adult amphibians. Adults are preyed upon by some mammals and snakes. Adult frogs and toads have poison glands in the skin which will secrete a mild toxin when they are threatened or attacked. When handling amphibians, be cautious not to touch your face and keep skin wounds covered, and wash your hands afterwards.

Salamanders

The wet, maritime climate of ONP is ideal for salamanders. Species fall into one of three categories: pond-breeding, stream-breeding, and terrestrial. All terrestrial salamanders in the Pacific Northwest have internal fertilization accomplished by the male depositing a spermatophore (sperm packet) on the substrate and the female picking it up with her cloaca. Pond-breeders have a distinct aquatic larval stage and terrestrial adult stage. Stream-breeders have an aquatic larval stage and, when mature, may remain in the water (like the paedomorphic Cope's giant salamander) or become terrestrial. Paedomorphic salamanders reproduce in the larval form. Terrestrial species do not have a larval stage. When the eggs hatch, they are miniature adults. Pond species breed in the spring. Stream species appear to have a prolonged breeding season spanning from spring to fall, and terrestrial species breed from fall through spring. Metamorphosis, for pond- and stream-breeders, occurs in three months to four years, depending on the species. All stream larvae appear to have the ability to overwinter.

Aquatic salamanders feed on plankton, aquatic insects, and amphibians. Terrestrial salamanders feed on insects, spiders, and likely anything else they can fit in their mouths. Predators of aquatic salamanders include amphibians, snakes, fish, predatory insects, mammals, and birds. Terrestrial salamanders are preyed upon by some mammals and snakes. Like frogs and toads, salamanders also secrete toxins as a defense against predators. Rough-skinned newts are especially poisonous. There is enough poison in one adult newt to kill 25,000 mice! Ensatina readily lose their tail as a defense mechanism. Predators may attack or swallow the tail while the owner scurries off to safety. The tail will grow back slowly.

Habitat Characteristics

Ponds and lakes were surveyed for amphibians at both low (sea level to 500m) and high elevations (500 to 1750m) in ONP from 1995—1998. Ponds at low elevations included those along the coastal strip and in valley bottoms. Ponds at high elevation ponds are located in the mountainous areas. There are few mid-elevation ponds. Generally, low elevation ponds are shallow with much emergent vegetation. Many pond-breeding amphibians attach their eggs to the stalks of aquatic vegetation. The water is warm and murky, rich in nutrients and algae. Tall trees and shrubs surround low elevation ponds providing shade for amphibians. At high elevations, ponds tend to have cold, clear water. While there is less algae, the coldness holds the dissolved oxygen longer than warm water. The trees at high elevations are shorter and less dense, providing less direct shade. High elevation lakes are often covered in snow during the winter. The larvae must metamorphose before the end of the summer season or over-winter in the substrate of the ponds.

Seeps and streams were also surveyed at varying elevations. Only streams that have water all year long will support amphibians although sometimes the water may be below the surface. Water levels may vary greatly, though. At low elevations in the valley bottoms, the streams are often nearly flat, shallow, and wide. The substrate is silt or mud with much aquatic vegetation. At higher elevations, the streams become steep and narrow. White water rushes over rocks, clearing out silt. Water temperature are colder at greater elevations. Tailed-frogs, Olympic torrent salamanders, and Cope's salamanders prefer the rocky, cold streams.

Western toads usually breed in ponds but, in the Olympic peninsula, they have also been found in the backwaters of rivers along valley bottoms. They are using potholes along the side of rivers, cut-off oxbows, or other backwaters for reproduction.

Ultraviolet Radiation

Amphibian populations have declined all over the world. One hypothesis is that ultraviolet-b radiation (UVB) negatively impacts amphibians. Stratospheric ozone depletion has caused UVB levels at northern temperate latitudes to increase in the past 20 years. Amphibians that breed in ponds often deposit eggs in shallow water where they are exposed to direct sunlight. Some studies have shown that eggs protected from UVB have greater hatching success than those not protected. However, dissolved organic carbon (DOC) may naturally inhibit UVB rays from traveling deep into the water.

At high elevation ponds in ONP, we took water samples and measured the distance UVB light was able to penetrate into the water. The ponds with high levels of DOC had less penetration (higher attenuation) by UVB which correlates with the distribution of breeding sites for the Cascades frog. More evidence is needed but it appears that Cascades frogs tend to breed, or survive best, in ponds where potentially harmful UVB is limited below the water surface.

Coastal Section of Olympic National Park

The Park's coastal land is home for a number of the low elevation pond breeders including: red-legged and Pacific tree frogs, rough-skinned newts, northwestern and long-toed salamanders, and western toads. These amphibians will utilize both permanent (e.g. James pond) and ephemeral ponds. There are historic records of western red-backed salamanders and Cascades frogs found along the coast but we have not found any in our surveys thus far.

To date, a few surveys in the streams of the coastal section suggest that no amphibians occur in them. Perhaps there are few stream-dwelling amphibians present and therefore, detection is more difficult. Alternatively the slow current, warm temperature, and high sediment loads of coastal waters may not be suitable for stream amphibians. Research is currently being done in this area and more information will be available at a later date.

Species of Concern

Some amphibians found in ONP are endemic to this area or to Washington state.

Cope's giant salamanders occur only in the Olympic mountains and Willapa Hills of western Washington and the southern Cascade mountains. It barely gets into northwestern Oregon. The terrestrial phase of Cope's giant salamander is very rare. Only three have been reported in the wild. Adults are usually found in streams in their paedomorphic form. Oddly, Cope's were found all over ONP except in streams from the Elwah to the Dosewallips drainages on the northeast side of the park. There are no historic records of Cope's being found there. Therefore, it is unknown if these data show a decline or unused habitat. This pattern needs further investigation.

In 1992, the genus *Rhyacotriton* (torrent salamanders) was split into four species. *Rhyacotriton olympicus* (Olympic torrent salamander) is found only on the Olympic peninsula. Van Dyke's salamanders occur in only three areas of Washington: Olympics, southern Cascades, and Willapa Hills. This species is rare and populations are small. Cascades frogs rarely occur below 2000 ft. but, between 1911-1919, Cascades frogs were collected at four different places near sea level on the Olympic peninsula. This suggests that they may have had a much broader distribution then now.

The Northwestern salamander is among the few salamanders that continue to survive in lakes with introduced fish. Our findings and those of other researchers suggest that long-toed salamanders and possibly Cascades frogs do not survive well with introduced, predatory fish. However, we found that Northwestern salamanders can frequently coexist with introduced fish in ONP.

Status of Amphibians in ONP

Overall there are few indications of serious amphibian decline in ONP; at least not of the magnitude that has been documented in other areas such as Colorado and California. In some parts of Colorado and California, toads and ranid frogs have virtually dissapeared. All of the species that were not marginal to ONP to begin with, were relatively common and widespread in our surveys although we do not have good historic information on the distribution and abundance of these species. We see little reason to believe that major changes have occurred.

In summary: 1) Some pond breeding species (long-toed salamander, Cascade frog) may not coexist well with introduced fish. This does not appear to be a major management concern because these amphibians are common and widespread in the many fishless ponds that are available. However, drought or global change could decrease small waters forcing remaining breeding into lakes with introduced fish. 2) Toads were more rare than we expected in montane ponds. They are very common in valley bottoms on the west side of ONP, but this is a species that was historically common at higher elevation in other parts of its range. It is also a species that has declined dramatically in other parts of its range. 3) Stream amphibians appear to be widespread and common in ONP. However, the absence of Cope's giant salamanders on the northeast side of the ONP is surprising because this species tends to be somewhat of a habitat generalist compared to the other stream breeding species and much suitable habitat in the northeast. Our analysis suggest that this pattern is not entirely a result of the southwest to northeast climate gradient. We recommend that water quality and potential pollution from the Seattle area be investigated.

Synopsis

1) Amphibians in the Pacific NW (& OLYM) are extremely unique
    a) High level of endemism
        i) Three endemic families (tailed frog, giant salamanders (4 spp), torrent salamanders (4 spp).
        ii) Many lungless salamanders are endemic to Pac. NW (e.g., Van Dyke's salamander only in Washington including OLYM).
    b) The tailed frog, giant salamanders, and torrent salamanders comprise a unique group of species that are highly adapted for life in torrential streams and seeps.
        i) The tailed frog is common in OLYM and is the most primitive and ancient frog still living. The 'tail' is a copulatory organ not found on any other frog.
        ii) Olympic torrent salamander is only on the Olympic peninsula.

iii) Cope's giant salamander is centered on Olympic peninsula with some pops in southern Washington Cascades and Willipa Hills.
c) OLYM and Redwoods are the only National Parks that have all three torrent breeding families.

2) Stream amphibians in OLYM
   a) Require cool, highly oxygenated water with rocky substrates. Generally associated with steep gradients.
   b) We have thoroughly surveyed streams (167) and seeps (200+) throughout the park.
   c) This survey provides a good 'snap-shot' of distribution patterns, but we don't know how variable these patterns are in time. For example, do populations frequently wink in and out?
   d) The Cope's giant salamander (endemic to the Olympic Peninsula and Willipa Hills) appears to be absent from the Elwha east down to at least the West Fork Dosewallips (we haven't surveyed the Duckabush).
   e) The Olympic torrent salamander is widespread on the west side but sparse on the east side of the park.
   f) We have refined stream and seep sampling techniques and have obtained much of the information necessary to develop and optimize a long-term monitoring plan for the park.
3) Pond amphibians in OLYM
   a) Pond amphibian communities in OLYM markedly change with elevation and are comprised of 3 frogs, 1 toad, 2 salamanders, and 1 newt.
   b) Anurans include the western toad and the Cascade frog which have been identified as species with widespread, mysterious declines in western North America. Toads are nearly extinct in Colorado and are thought to be declining in Oregon and California. Cascade frogs are virtually extinct in Lassen Volcano national Monument.
   c) Cascade frogs appear common and widespread in OLYM, but breeding is confined to small (often ephemeral) ponds.
      i) Larger waters typically have non-endemic fish which may be detrimental to Cascade frogs, but more research is needed to document this relationship.
   d) We rarely encountered western toads in our surveys, but some historic data suggest they were always rare throughout much of the park.
      i) To assess the status of toads, we need to survey more montane ponds and examine river backwaters, where toads appear to breed on the Olympic peninsula. This is extremely important as the status of toads in Washington is largely unknown and is poorly documented in Oregon. We need to thoroughly assess all possible toad habitats in the park, hopefully before the onslaught of severe declines seen in Colorado.
   e) Other pond amphibians appear widespread.
   f) We have refined techniques for surveying pond amphibians in OLYM.
4) Terrestrial amphibians in OLYM
   a) 3 species: Ensatina, western red-backed salamander, and Van Dyke's salamander (this species mostly occurs in seeps, but appears to have a restricted distribution in the park).
   b) Status of terrestrial species is unknown.
5) We have made substantial progress in OLYM, but it is now important that work continues on long-term monitoring. Olympic is one of the best western parks to focus amphibian monitoring:
   a) The diverse, unique amphibian fauna in Olympic is not represented in any other park, but portions of the Olympic fauna occur in other parks. For example, tailed frogs are also present in NOCA, MORA, and Redwoods, but NOCA and MORA lack giant salamanders and torrent salamanders. OLYM is the best

representative of the Pacific NW parks.

b) Elevational and climatic gradients in Olympic are ideal for monitoring global change. Many amphibian species appear sensitive to these gradients.

c) Other western parks have historically or currently depauperate amphibian faunas. None provide the opportunity that Olympic does to monitor population changes in a variety of species and habitats over environmental gradients.

d) The absence of documented declines in Olympic does not mean that it is ‘safe’.

6) Monitoring Needs in OLYM
   a) Long-term monitoring of all three amphibian groups: stream/seep breeders, pond breeders, and terrestrial breeders.
      i) We have baseline data for stream/seep and pond habitats, but more pond surveys are needed (including river backwaters which have been overlooked so far). Sampling techniques are well developed for stream/seep and pond habitats.
      ii) We need to invest in developing and optimizing a long-term monitoring plan (including power to detect trends vs. funds, and spatial coverage).
      iii) We need to develop reliable sampling techniques for terrestrial amphibians and conduct baseline surveys. These surveys can be used to assess current status and develop long-term monitoring plans.

7) Research Needs in OLYM
   a) Global change brings a variety of potential threats to amphibians which are an especially sensitive group because of their bi-phasic life cycles, permeable skin and eggs, and their sensitivity to temperature, precipitation, and hydrology.
   b) Besides extensive monitoring of amphibian distribution patterns, we need to conduct intensive population monitoring in association with various potential ‘stressors’ including UVB, nitrogen deposition, hydrological fluctuations, changes in temperature and precipitation, and airborn contaminants.
      i) Stressors potentially interact with each other and with other factors. These interactions need to be studied to understand how environmental change will ultimately affect amphibians.
         (1) For example, the main factors affecting the exposure of aquatic organisms to UVB are dissolved organic carbon (DOC) levels and behavioral attributes of the organisms.
            (a) Can organisms change behavior to mediate UVB exposure?
            (b) How does DOC level affect behavior and larval food supply?
            (c) How do behavior and DOC interact with projected changes in precipitation and hydrology?
   c) Some life history attributes of amphibians are plastic and are expected to respond to changing climate. We need to study the level of ecological plasticity and learn to use life-history characteristics to forecast population changes.
   d) Non-endemic fish.
      i) We have added to correlative evidence that non-endemic fish are detrimental to anurans (e.g., Cascade frog).
      ii) We need intensive work including fish removal to assess fish impacts on amphibians and the potential for recovery.
      iii) We also need to study how fish interact with global change factors such as DOC, nitrogen, and climate.

Table 17. Amphibians of Olympic National Park.

Scientific Name	Common Name	Abundance in ONP	Breeding Habitat	Elevation*
Hyla regilla	Pacific tree frog	Intermittent	Ponds	Primarily low, few high
Rana aurora	Red-legged frog	Intermittent	Ponds	Low
Rana cascadae	Cascades frog	Common	Ponds	High
Ascaphus truei	Tailed frog	Common	Streams	Primarily high, some low
Bufo boreas	Western toad	Intermittent	Ponds	Low
Ambystoma gracile	Northwestern salamander	Common	Ponds	Primarily low, some high
Ambystoma macrodactylum	Long-toed salamander	Intermittent	Ponds	High
Taricha granulosa	Rough-skinned newt	Intermittent	Ponds	Primarily low, some high
Dicamptodon copei	Cope's giant salamander	Common	Streams	Primarily high, some low
Rhyacotriton olympicus	Olympic torrent salamander	Common	Streams or seeps	Low and High
Plethodon vandykei	Van Dyke's salamander	Rare	Land	Primarily low, few high
Plethodon vehiculum	Western red-backed salamander	Intermittent	Land	Primarily low, few high
Ensatina eschscholtzii	Ensatina	Intermittent	Land	Primarily low, few high

* Low elevation is defined as sea level to 500 meters. High elevation is from 500 meters and above.

APPENDIX B. STREAM LOCATIONS

Stream	Drainage	UTMN	UTME
96201	MORSE	5319810	468300
96202	MORSE	5318780	470120
96203	MORSE	5318310	471000
96204	MORSE	5314600	467050
96205	MORSE	5314500	466625
96206	MORSE	5314780	465700
96207	SOLEDUCK	5324340	427530
96208	SOLEDUCK	5324150	426510
96209	SOLEDUCK	5313480	435480
96210	SOLEDUCK	5311430	437870
96211	SOLEDUCK	5311260	438290
96212	SOLEDUCK	5311120	439650
96213	SOLEDUCK	5309970	441480
96214	SOLEDUCK	5309800	441570
96215	SOLEDUCK	5309720	441840
96216	SOLEDUCK	5309240	434050
96217	SOLEDUCK	5309200	443290
96218	SOLEDUCK	5308790	444260
96219	GRAY WOLF	5301380	480790
96220	GRAY WOLF	5300660	479680
96221	GRAY WOLF	5300140	479200
96222	ELWHA	5320570	456220
96223	ELWHA	5316350	455590
96224	ELWHA	5315720	455720
96225	ELWHA	5314920	455630
96226	ELWHA	5314750	452700
96227	LYRE	5323240	433270
96228	ELWHA	5313460	456420
96229	LYRE	5321860	440200
96230	LYRE	5321960	440320
96231	LYRE	5322220	435150
96232	LYRE	5321780	439830
96233	NORTH FORK SOLEDUCK	5317070	434050
96234	NORTH FORK SOLEDUCK	5316880	434430
96235	NORTH FORK SOLEDUCK	5317100	437330
96236	NORTH FORK SOLEDUCK	5317220	437580
96237	NORTH FORK SOLEDUCK	5317170	438750
96238	NORTH FORK SOLEDUCK	5317100	438920
96239	NORTH FORK SOLEDUCK	5317900	440260
96240	NORTH FORK SOLEDUCK	5316900	442650
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96242	ELWHA	5318050	456170
96243	ELWHA	5317920	456240
96244	ELWHA	5316970	456000
96245	ELWHA	5316420	454410
96246	ELWHA	5315480	454630
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96248	ELWHA	5305290	463610
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96253	ELWHA	5299830	465360
96254	ELWHA	5299300	465430
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96257	ELWHA	5293050	466250
96258	ELWHA	5291940	466440
96259	ELWHA	5291700	466200
96260	ELWHA	5290700	465950
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96262	ELWHA	5287440	462230
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97013	BOGACHIEL	5306520	425210
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97025	BOGACHIEL	5308600	432070
97043	HOH	5302980	447830
97044	HOH	5302710	448050
97045	HOH	5302620	448190
97046	HOH	5299730	448170
97047	HOH	5299350	448120
97106	NORTH FORK QUINAULT	5280480	455270
97107	NORTH FORK QUINAULT	5281720	455700
97108	NORTH FORK QUINAULT	5284810	457290
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97111	NORTH FORK QUINAULT	5275820	451190
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97119	EAST FORK QUINAULT	5271740	461230
97120	QUEETS	5266930	409880
97122	QUEETS	5268770	412150
97123	QUEETS	5269160	414520
97124	QUEETS	5271760	418220
97125	QUEETS	5273210	422020
97126	LAKE QUINAULT	5258330	432080
97127	LAKE QUINAULT	5258400	432170
97128	LAKE QUINAULT	5258630	432590
97129	LAKE QUINAULT	5259286	434081
97178	LAKE QUINAULT	5260880	436560
97180	LAKE QUINAULT	5260080	435120
97181	LAKE QUINAULT	5258620	432340
97182	LAKE QUINAULT	5260640	435890
97183	LAKE QUINAULT	5261610	439720
97184	LAKE QUINAULT	5261880	440010
97185	LAKE QUINAULT	5260860	436540
97193	HOH	5301920	433920
97194	HOH	5296460	423010

Stream	Drainage	UTMN	UTME
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97200	HOH	5301510	435700
97221	BOGACHIEL	5303800	406930
97222	BOGACHIEL	5303780	407640
97223	BOGACHIEL	5304240	409030
97224	BOGACHIEL	5304120	409200
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97226	BOGACHIEL	5303950	410070
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97231	BOGACHIEL	5303830	412550
97232	BOGACHIEL	5303560	413880
97233	BOGACHIEL	5303700	414210
97234	BOGACHIEL	5303360	414400
97235	BOGACHIEL	5303530	415050
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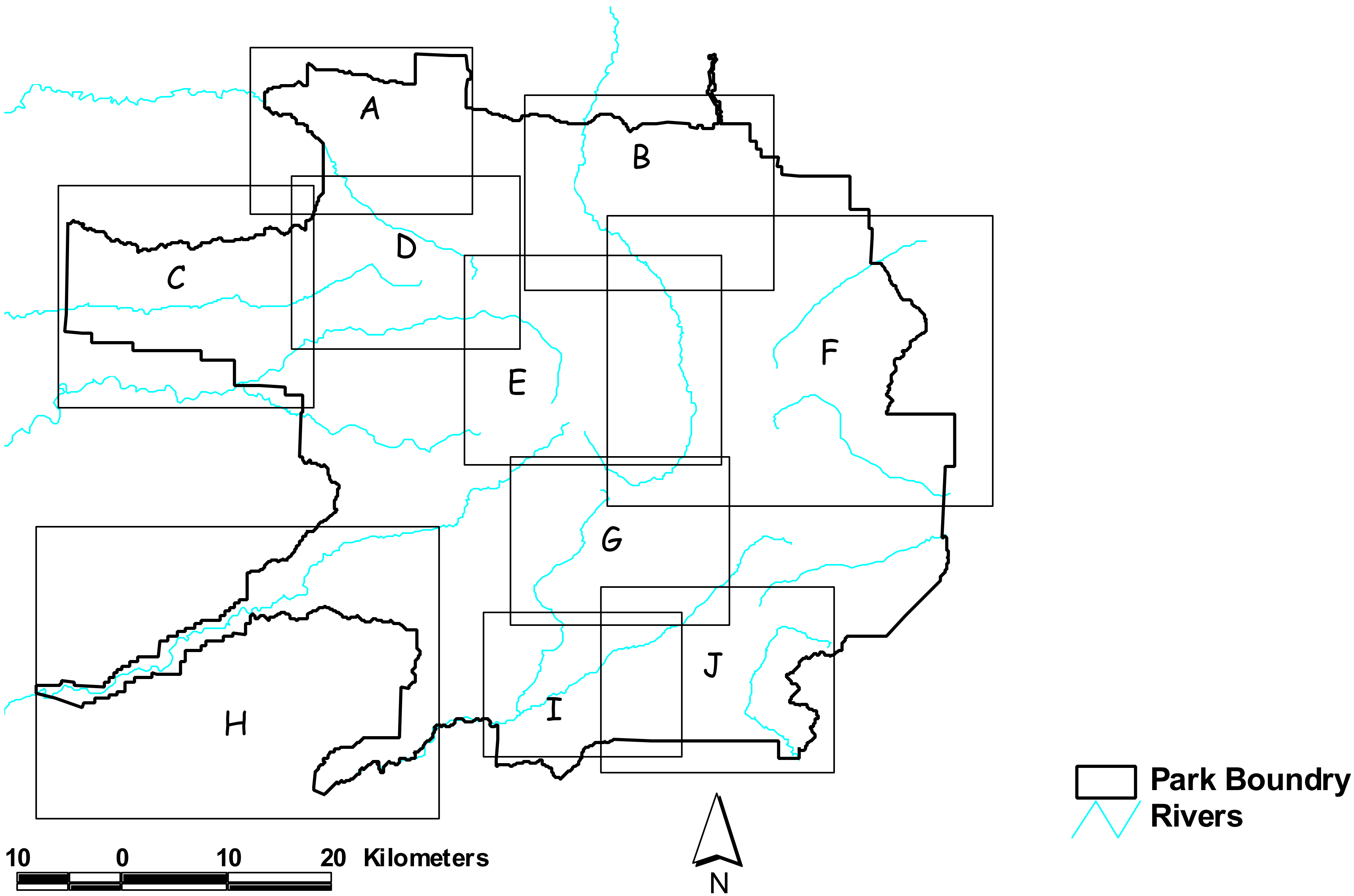
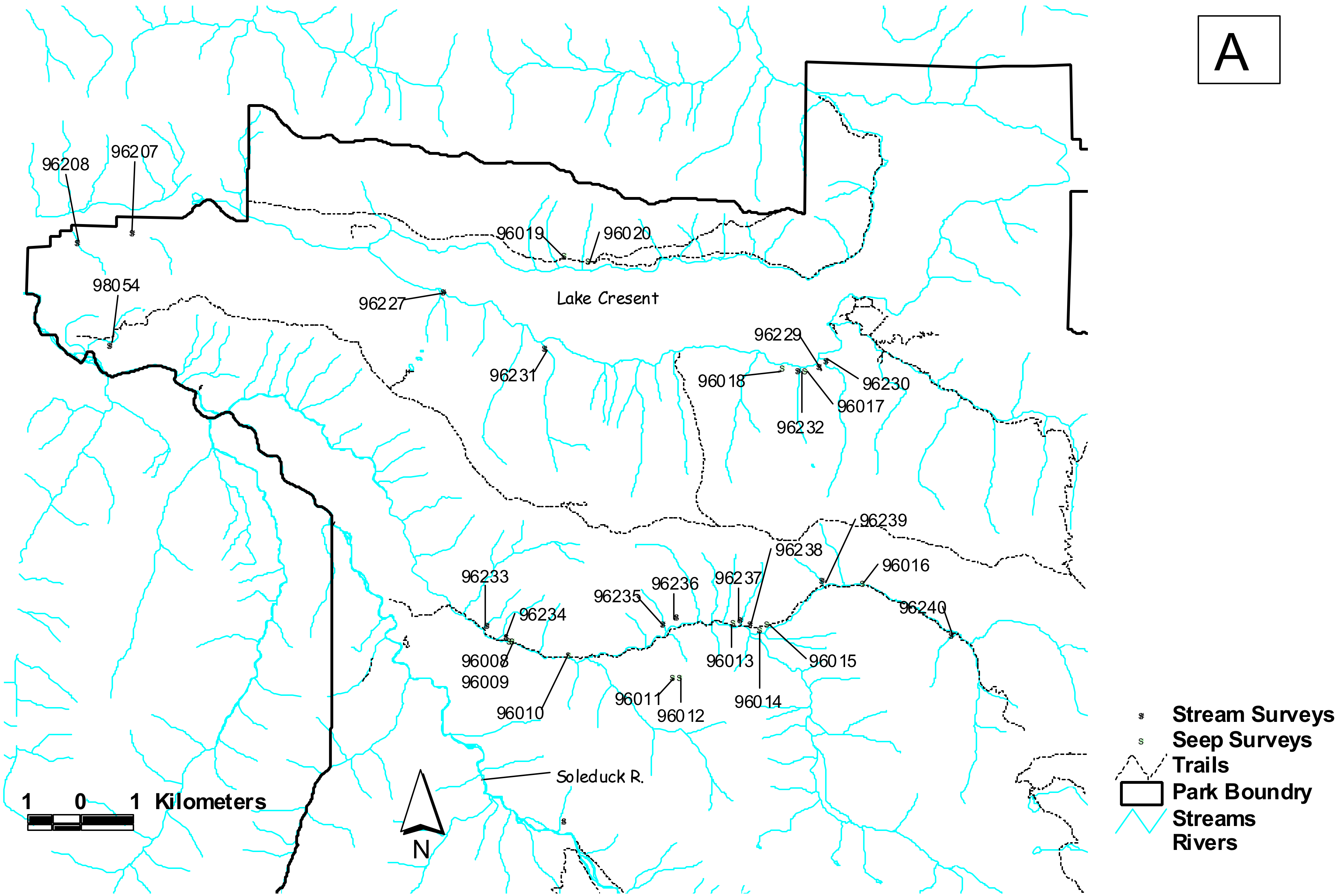
98002	GRAY WOLF	5304480	478800
98003	GRAY WOLF	5308200	476240
98004	GRAY WOLF	5306700	474820
98005	GRAY WOLF	5304750	472620
98006	GRAY WOLF	5304480	472640
98034	SKOKOMISH	5261550	475925
98035	SKOKOMISH	5263120	475000
98036	SKOKOMISH	5263265	474760
98037	SKOKOMISH	5266000	471880
98038	SKOKOMISH	5269720	471600
98039	SKOKOMISH	5274240	475190
98040	SKOKOMISH	5274640	475860
98041	DOSEWALLIPS	5287580	486440
98042	DOSEWALLIPS	5287700	485680
98043	DOSEWALLIPS	5288710	483760
98044	DOSEWALLIPS	5291800	480680
98045	DOSEWALLIPS	5293720	480240
98046	DOSEWALLIPS	5294120	479900
98047	DOSEWALLIPS	5287200	487460
98048	DOSEWALLIPS	5287480	486790
98054	SOLEDUCK	5322265	427120
98055	SOLEDUCK	5310920	439470
98056	SOLEDUCK	5310480	441025
98057	SOLEDUCK	5309120	443510
98058	SOLEDUCK	5308820	444330
98060	DOSEWALLIPS	5287880	485580

APPENDIX C. MAPS OF STREAM AND SEEP SURVEY LOCATIONS.

These are detailed maps of stream and seep survey sites. Site coordinates are in Appendix B.

Survey Locator

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96013
96015
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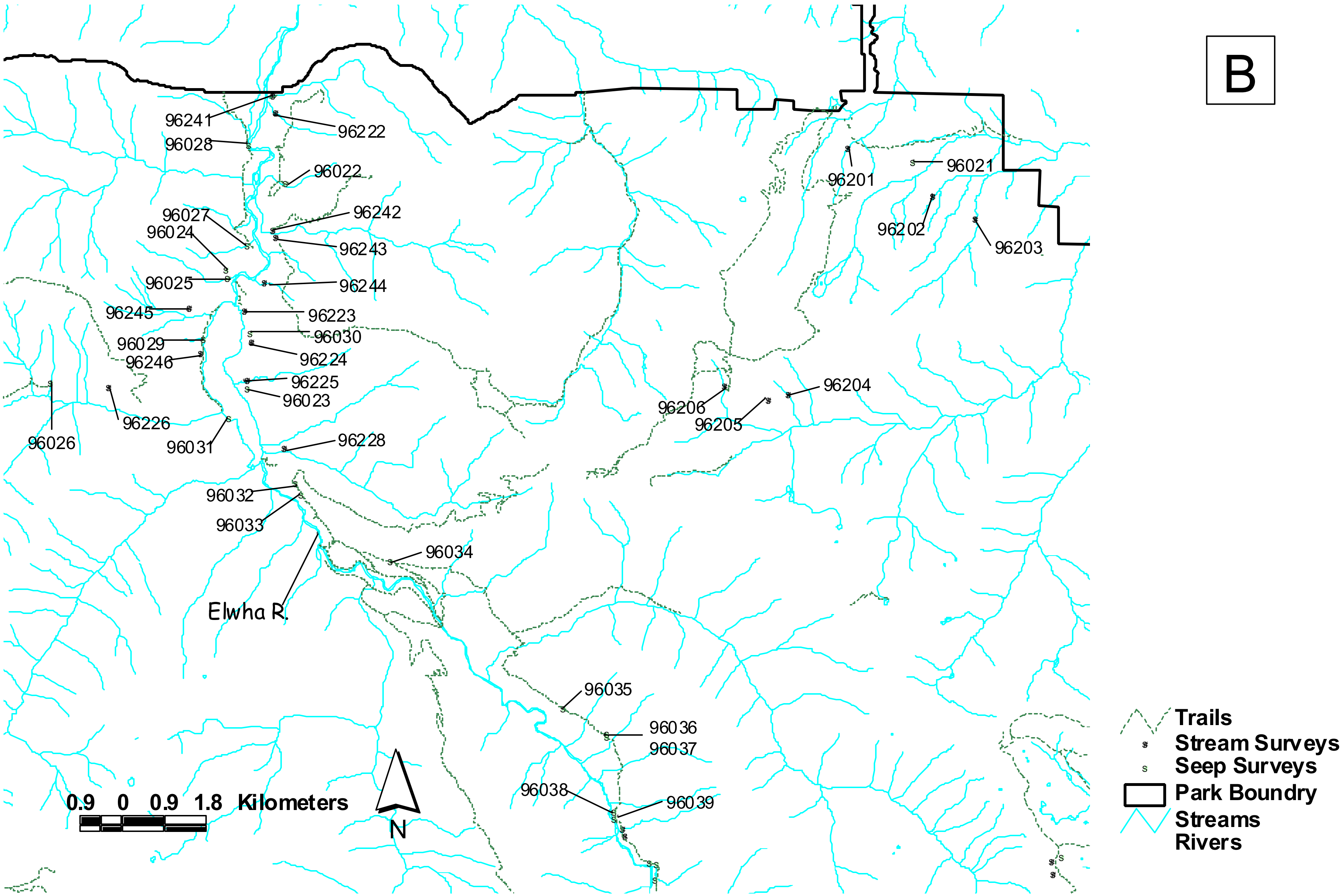
Stream Surveys
Seep Surveys
Trails
Park Boundry
Streams
Rivers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Elwha R.
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96201
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96202
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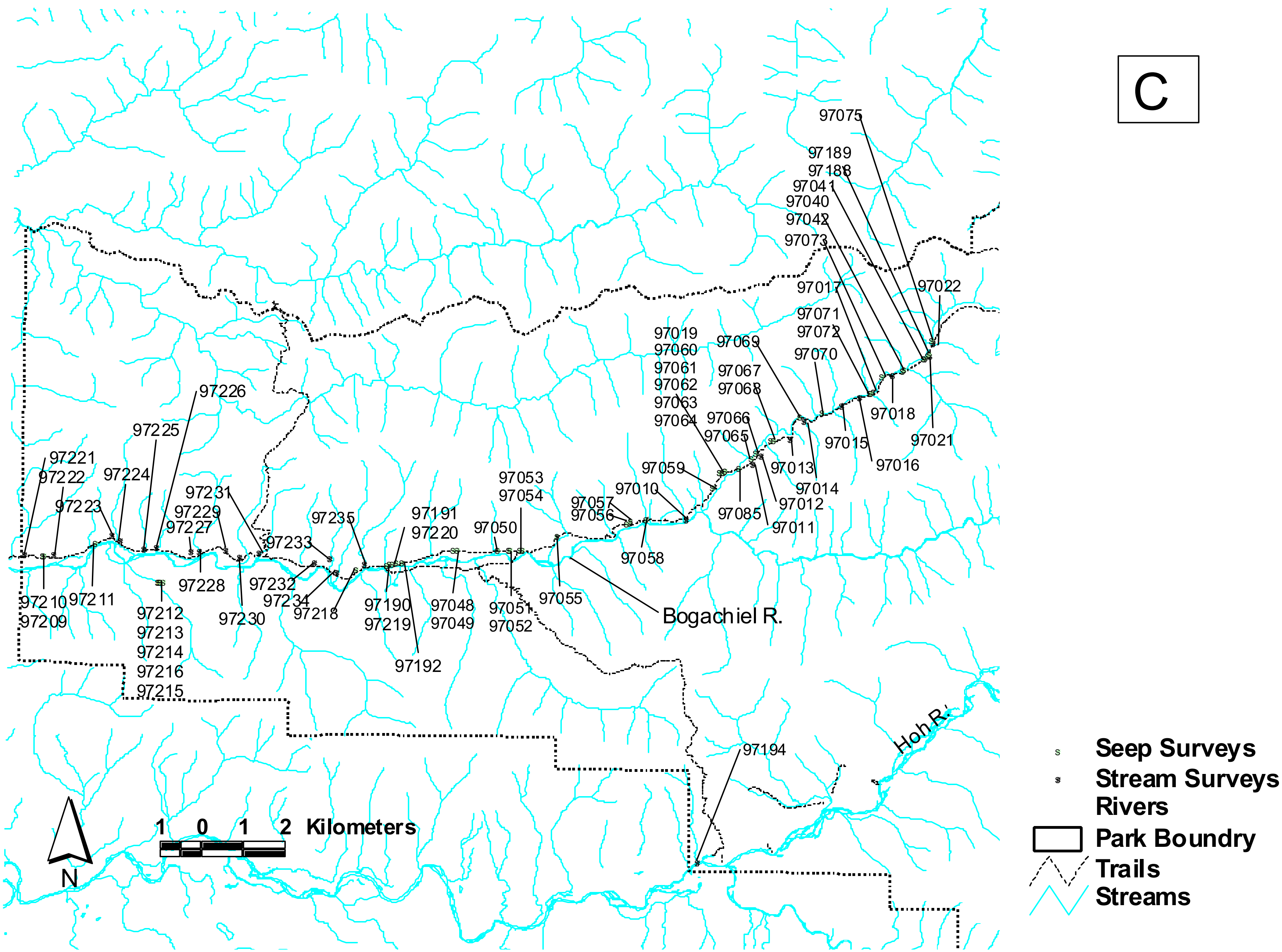
Trails
Stream Surveys
Seep Surveys
Park Boundry
Streams
Rivers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Hoh R.
97194
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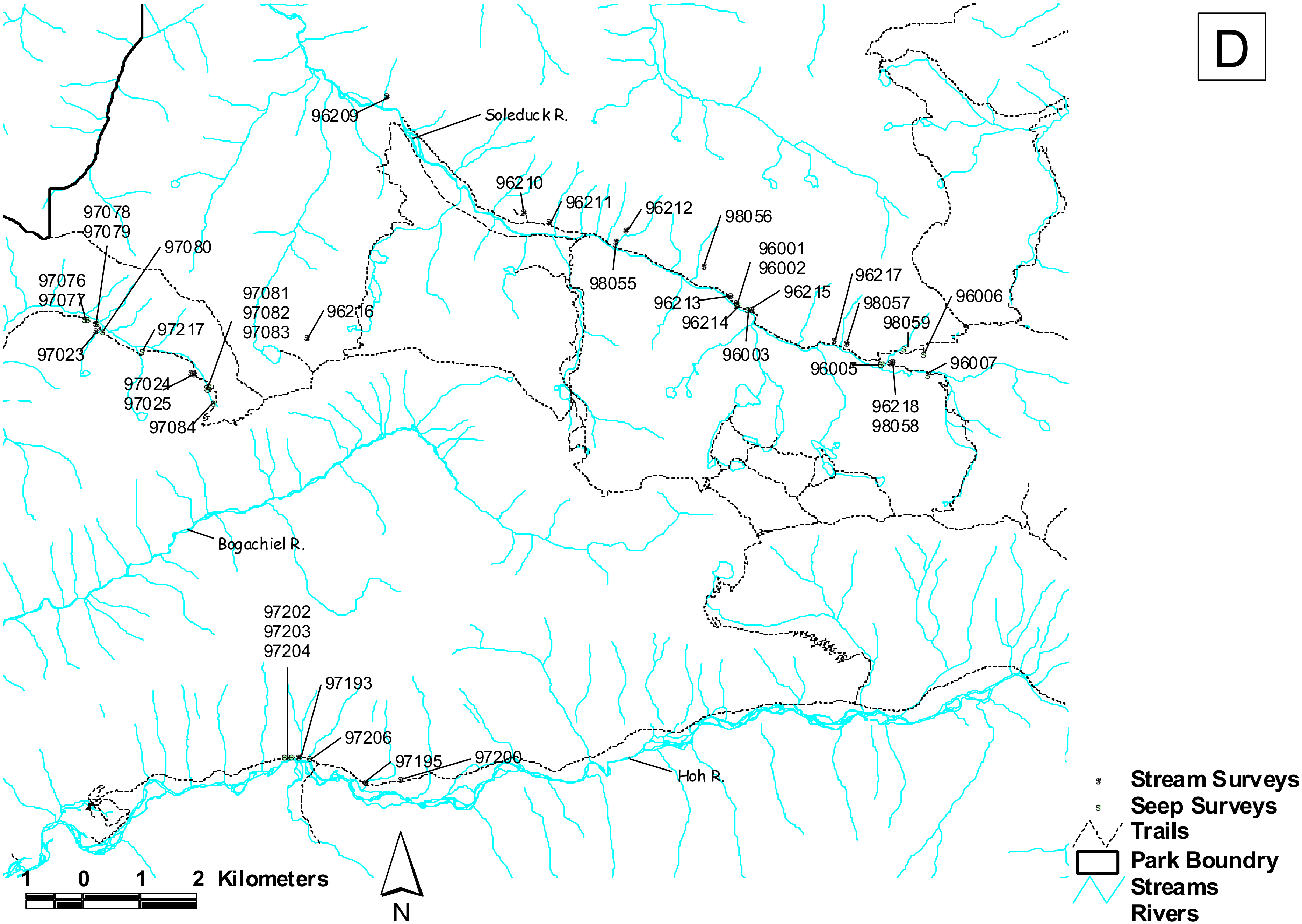
Stream Surveys
Rivers
Park Boundry
Trails
Streams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97084
Bogachiel R.
97202
97203
97204
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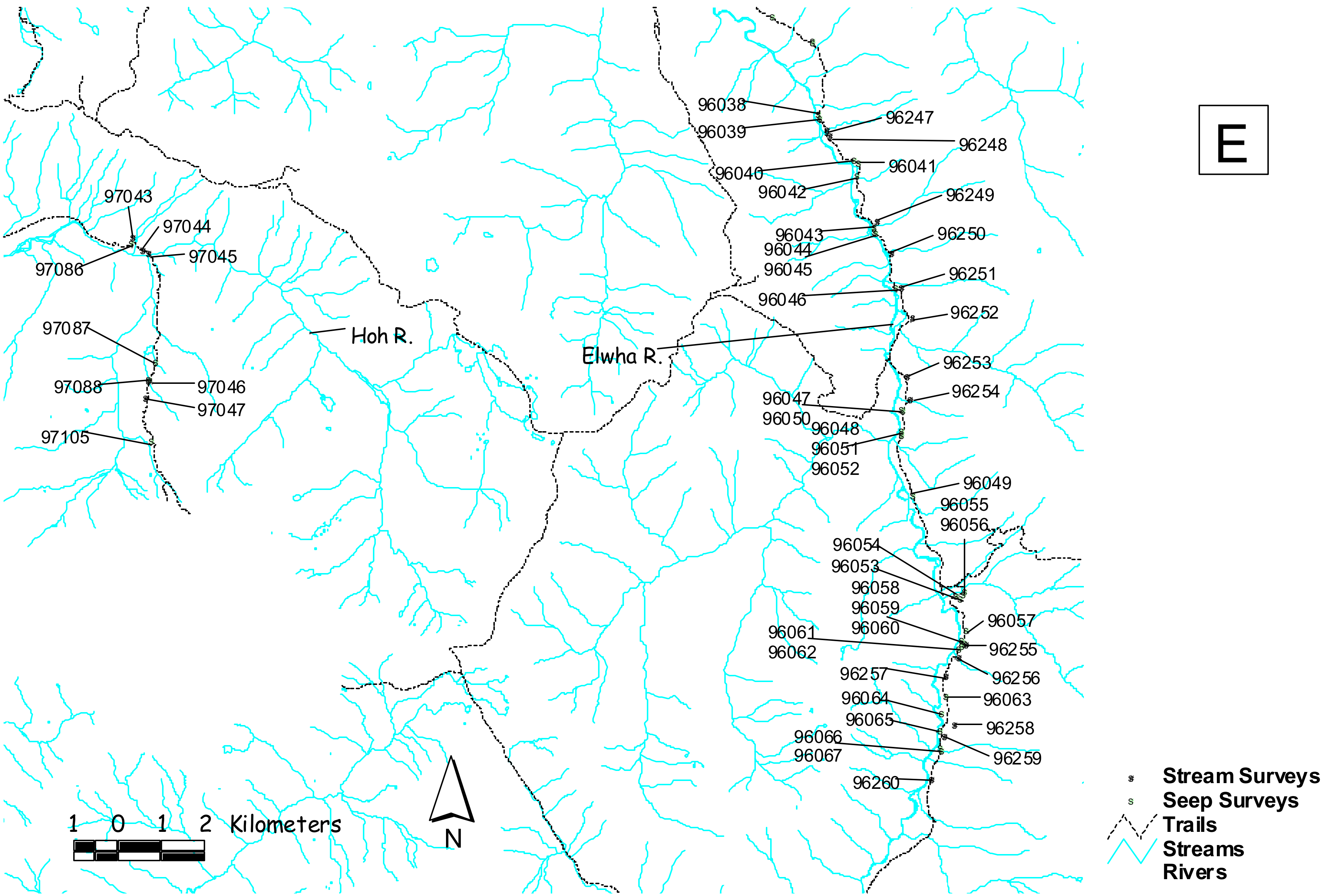
Stream Surveys
Seep Surveys
Trails
Park Boundry
Streams
Rivers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Elwha R.
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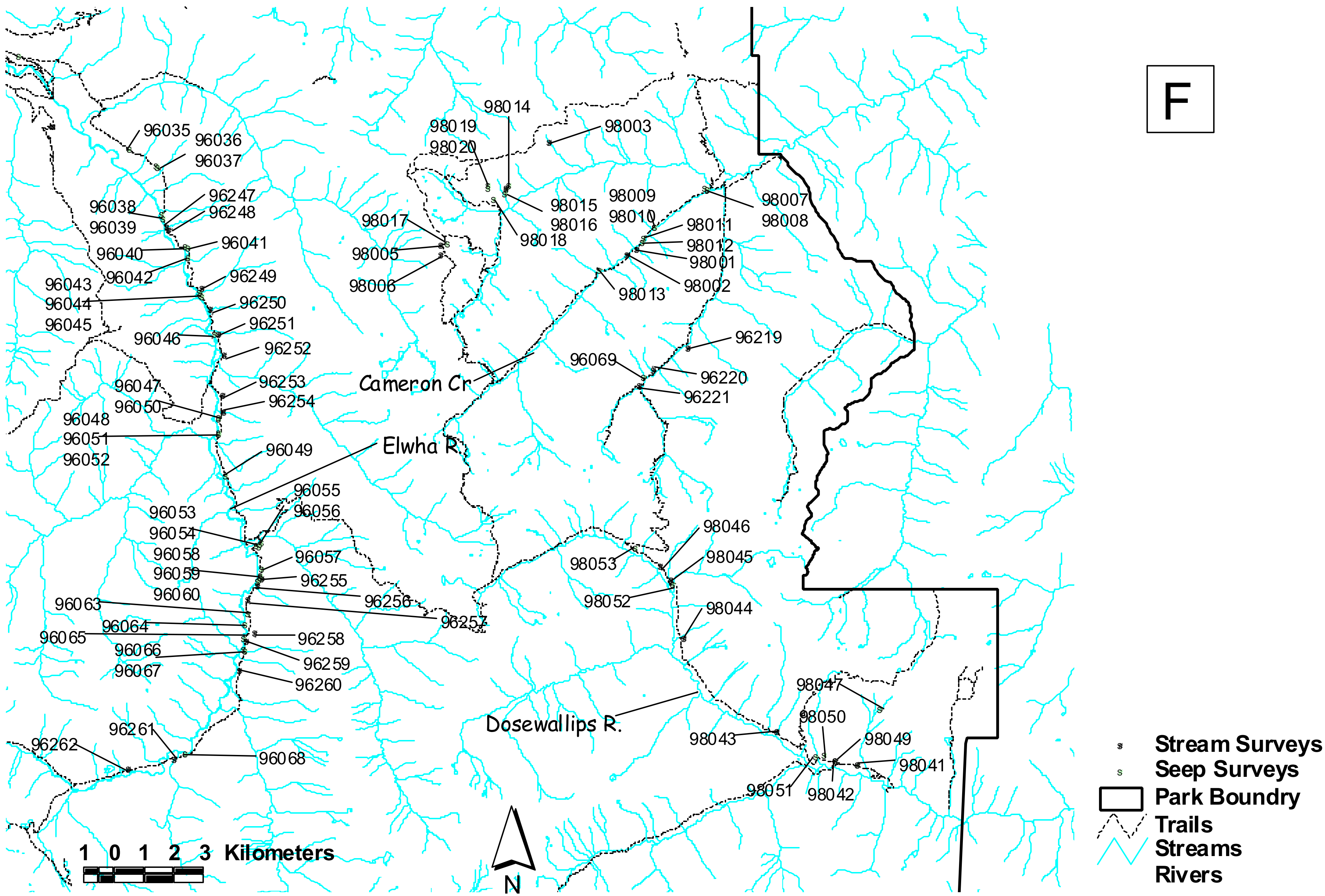
Stream Surveys
Seep Surveys
Trails
Streams
Rivers



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Elwha R.
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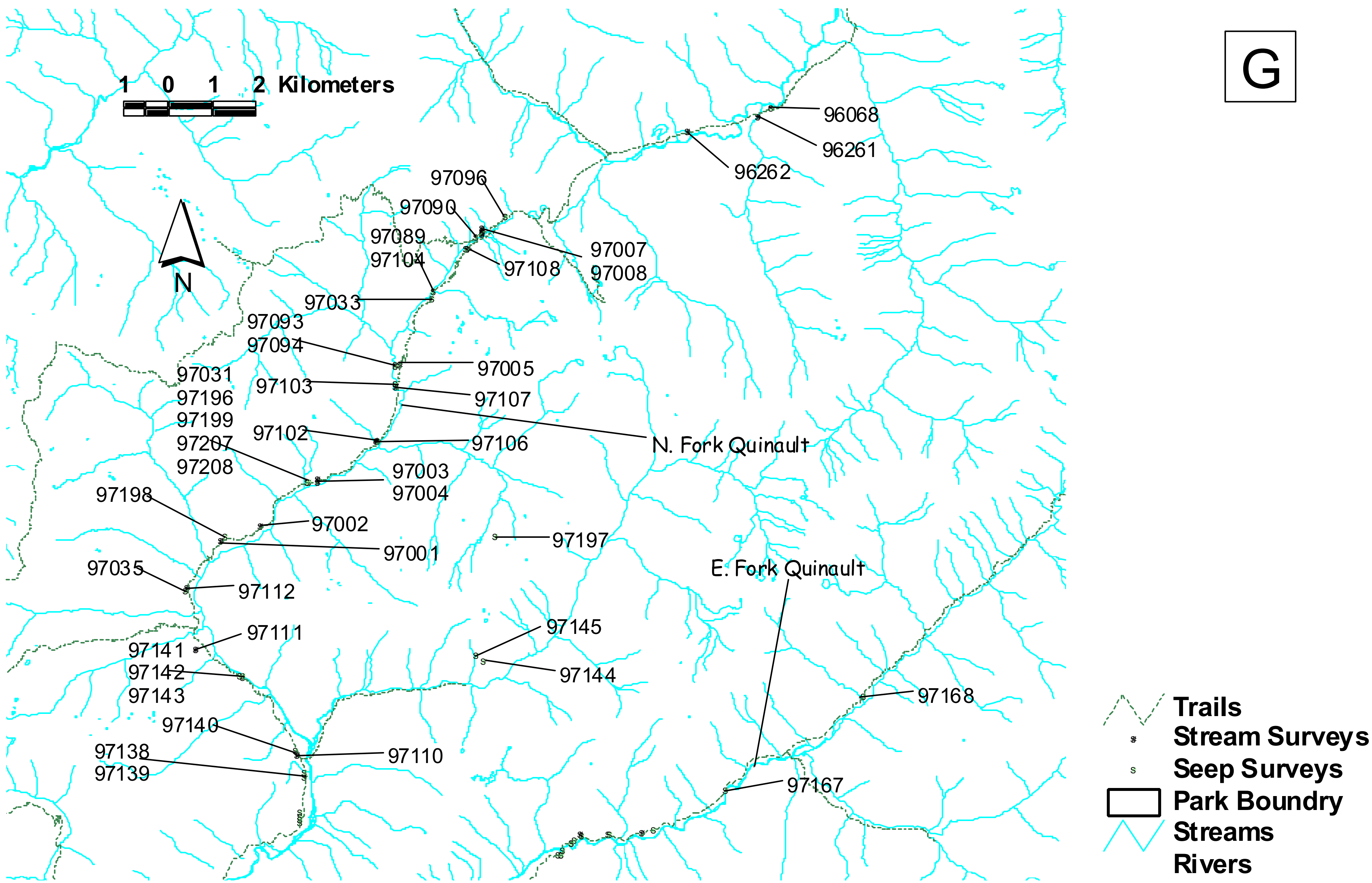
Stream Surveys
Seep Surveys
Park Boundry
Trails
Streams
Rivers



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97197
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E. Fork Quinault
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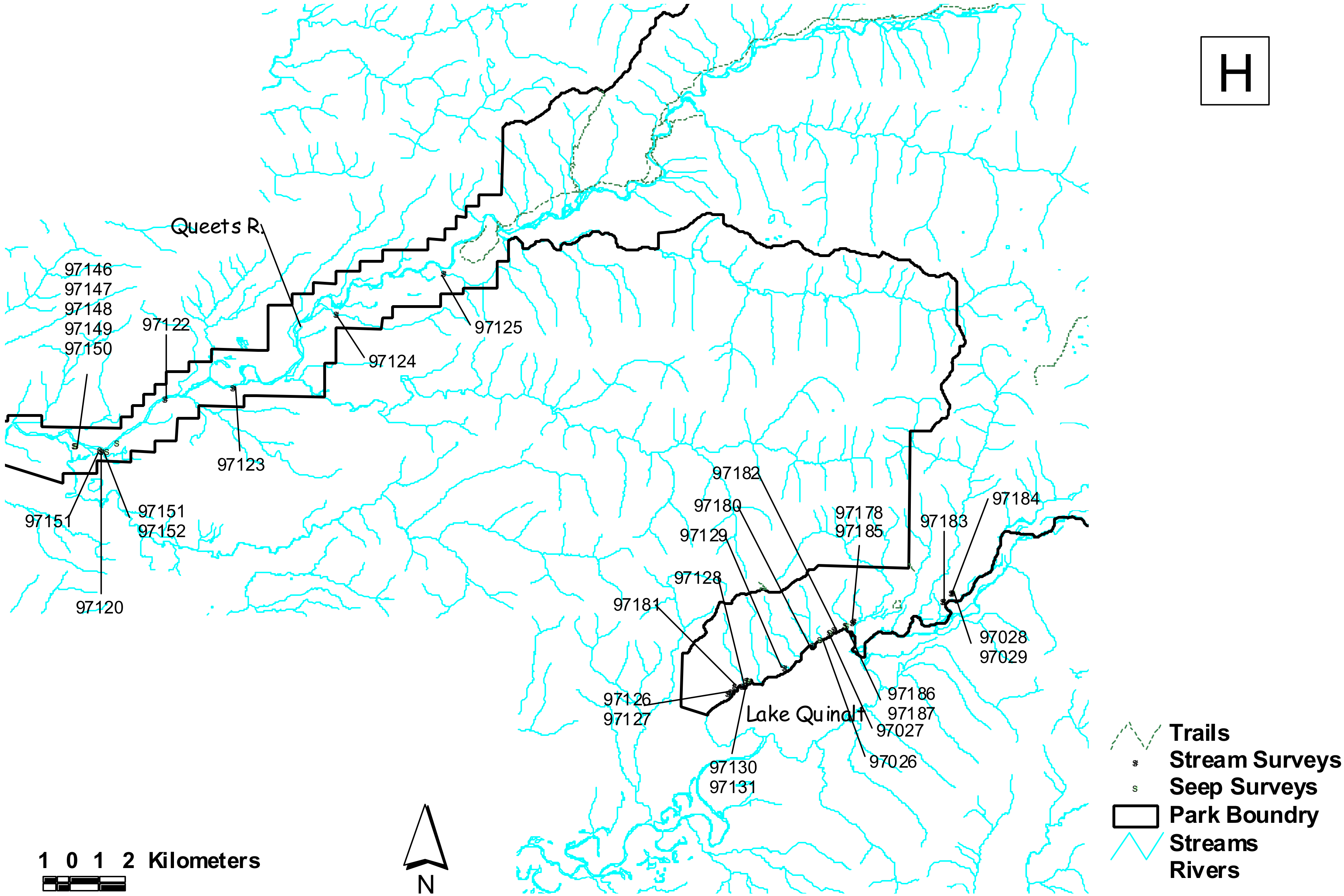
Stream Surveys
Seep Surveys
Park Boundry
Streams
Rivers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Lake Quinalt
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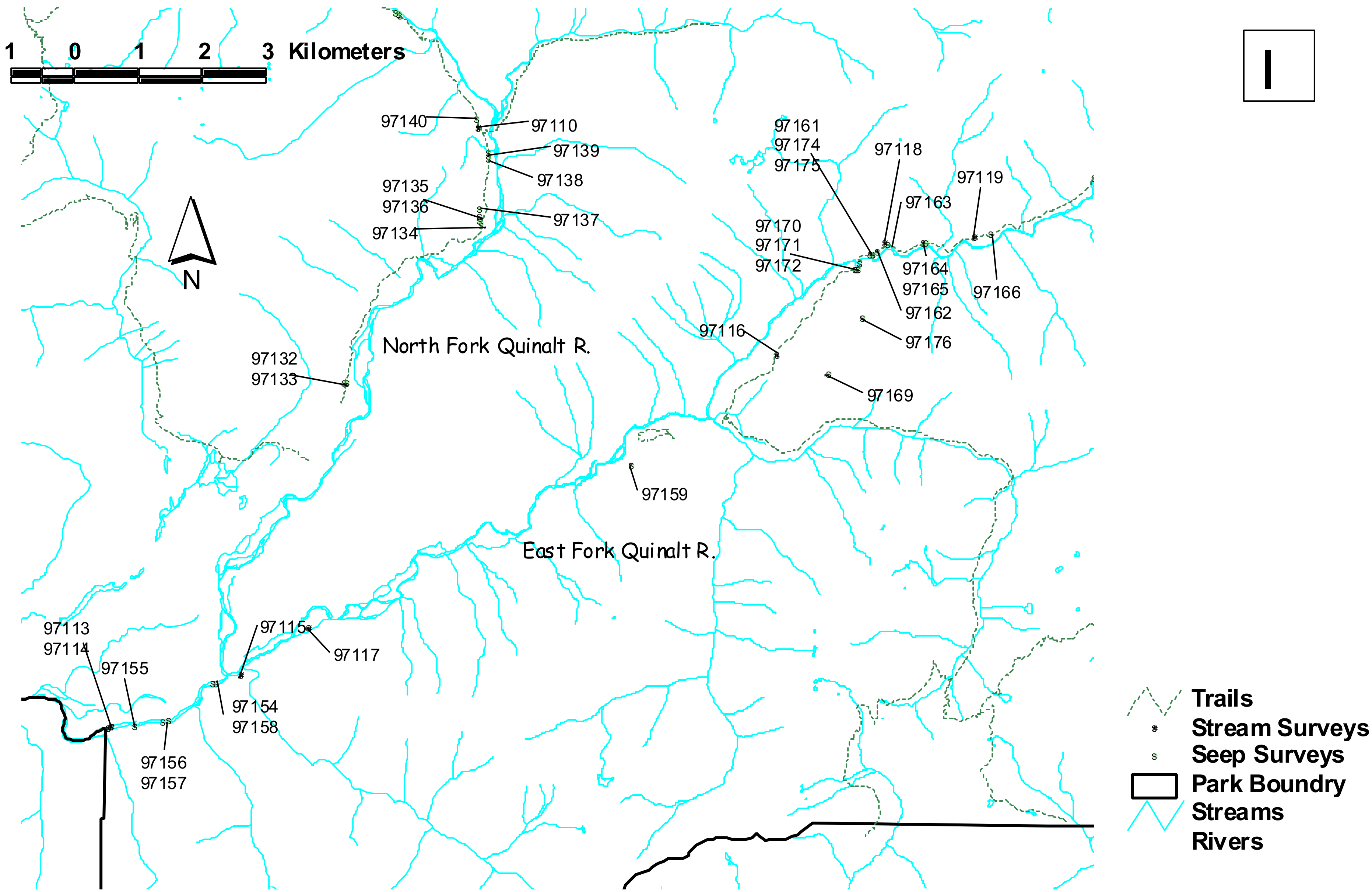
Trails
Stream Surveys
Seep Surveys
Park Boundry
Streams
Rivers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East Fork Quinalt R.
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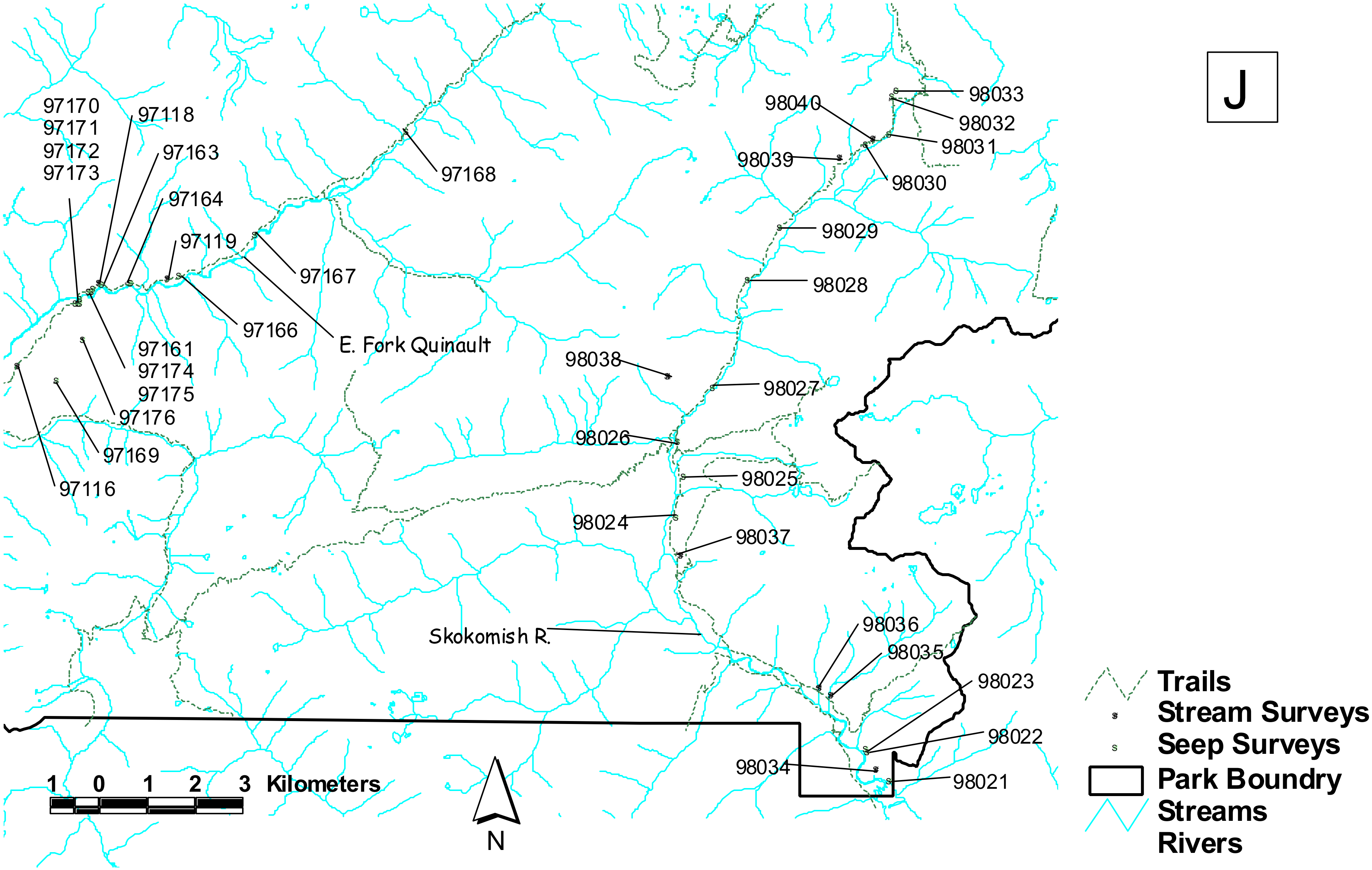
Stream Surveys
Seep Surveys
Park Boundry
Streams
Rivers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Skokomish R.
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Stream Surveys
Seep Surveys
Park Boundry
Streams
Rivers

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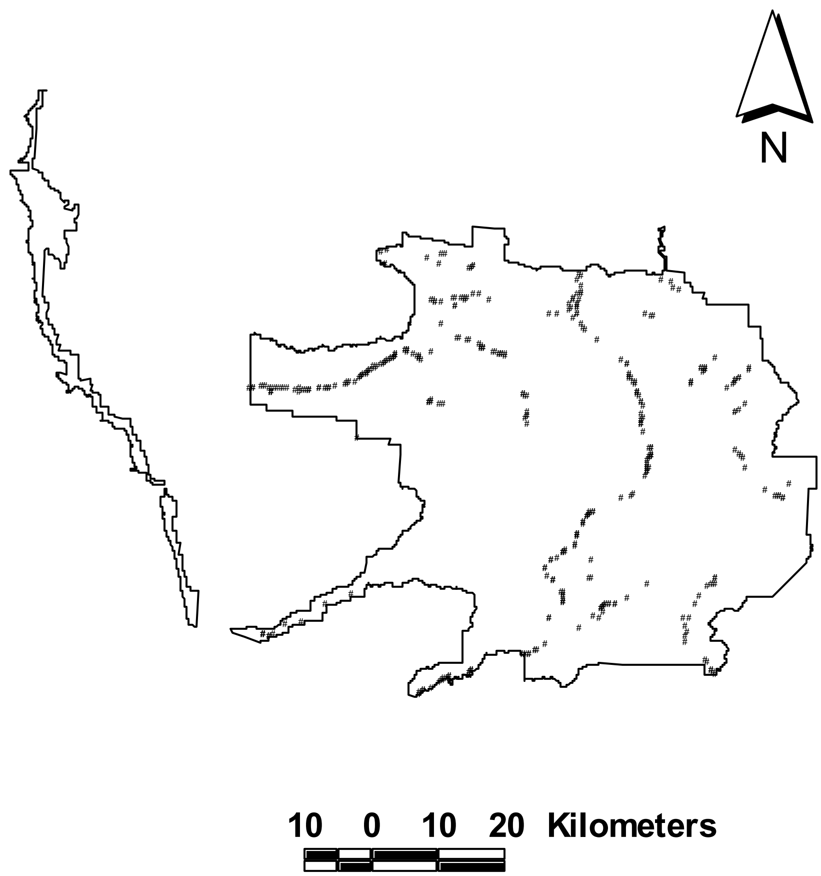
APPENDIX D. MAPS OF AMPHIBIAN DETECTIONS IN STREAMS AND SEEPS

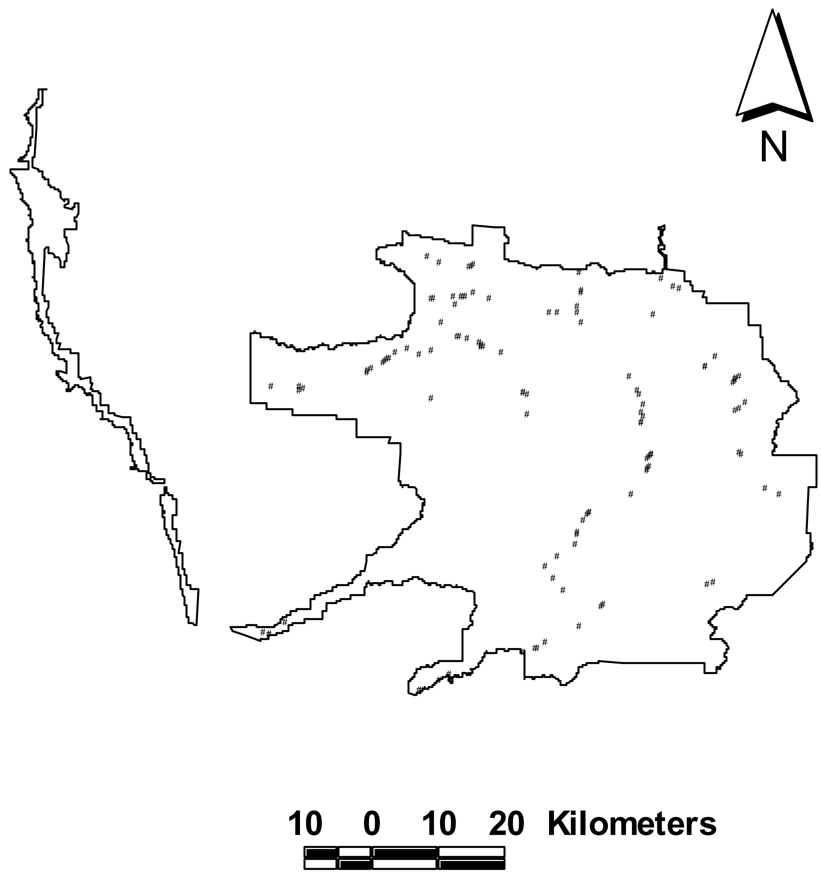
The following series of maps show the locations of amphibian detections in streams and seeps in Olympic National Park. We combined stream and seep surveys for these maps because both provide breeding habitat for tailed frogs, Cope’s giant salamanders, and Olympic torrent salamanders. Seeps also provide habitat for Van Dyke’s salamanders.

Map 1 shows the location of all stream and seep surveys. Subsequent maps show amphibian detections. These maps are intended as an overview of survey results. Detailed maps of survey sites are in Appendix C.

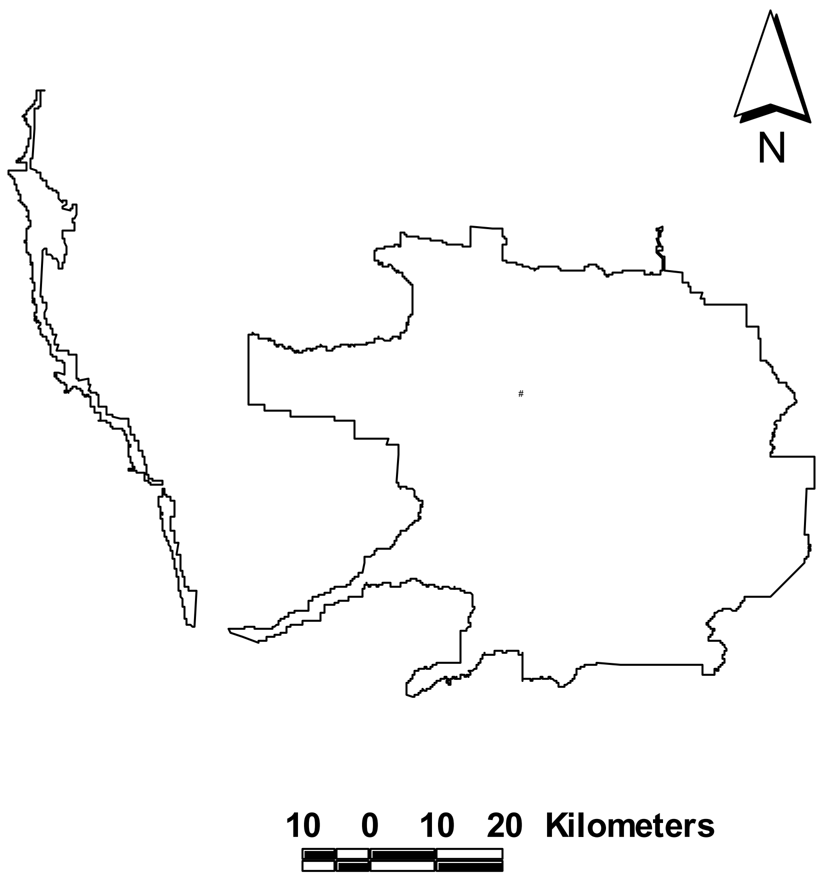
Stream and Seep Surveys



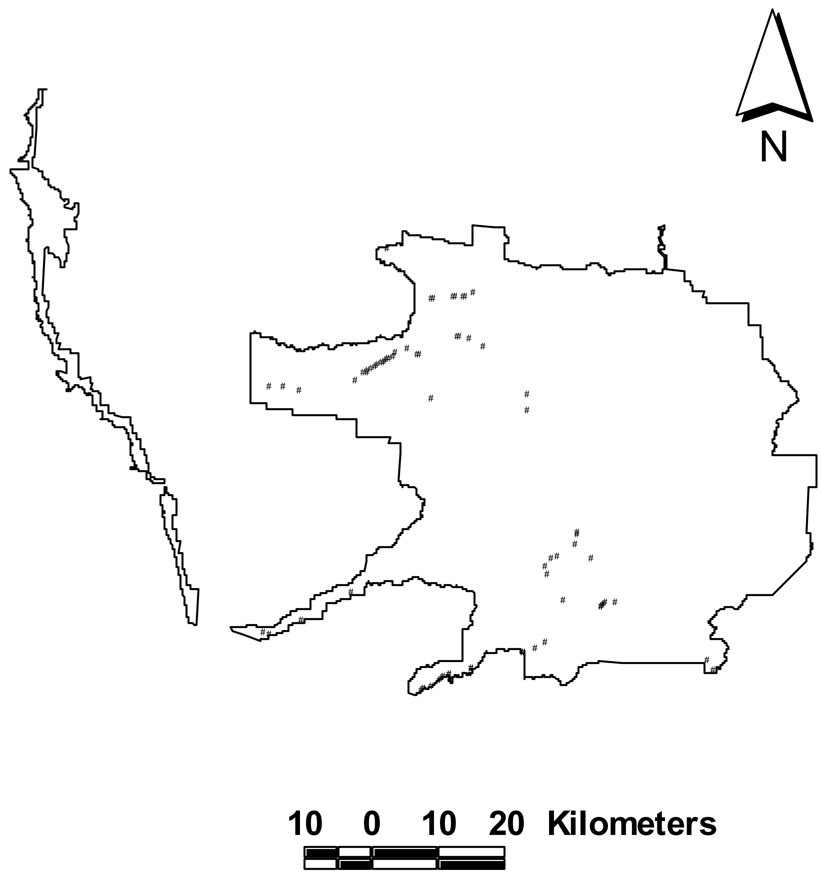
Tailed Frog



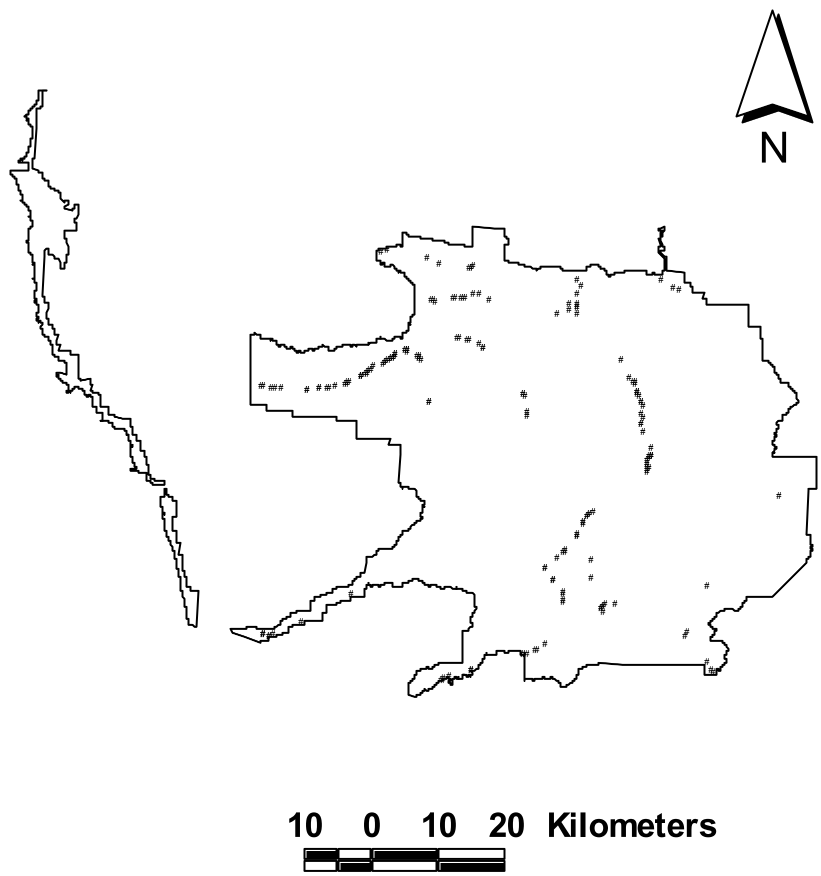
Cascades Frog



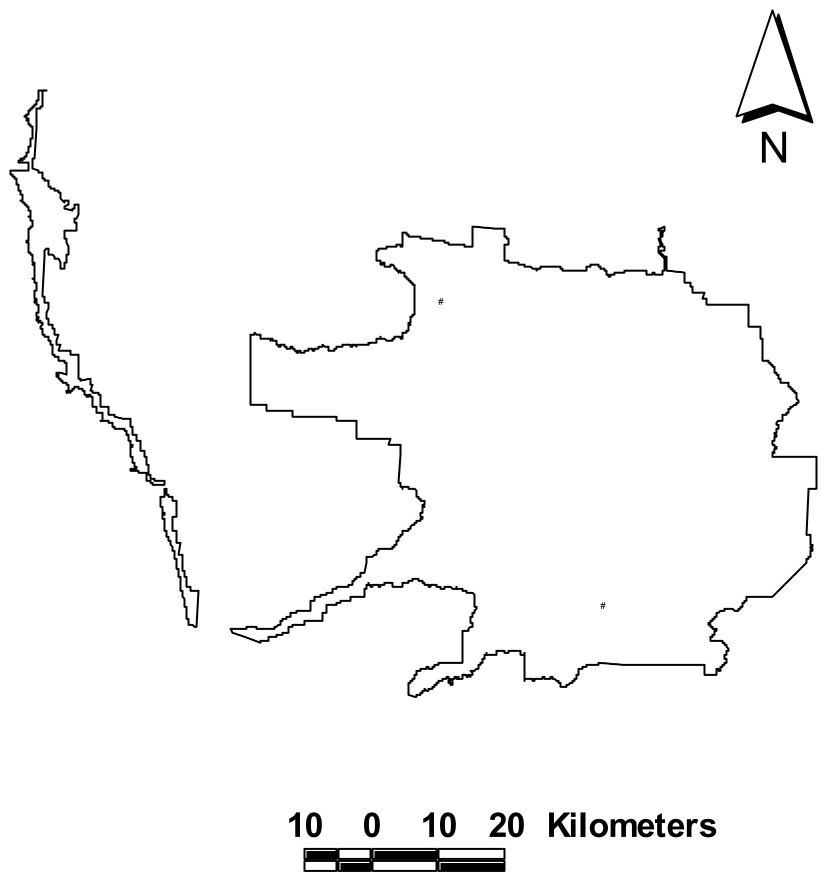
Cope's Giant Salamander



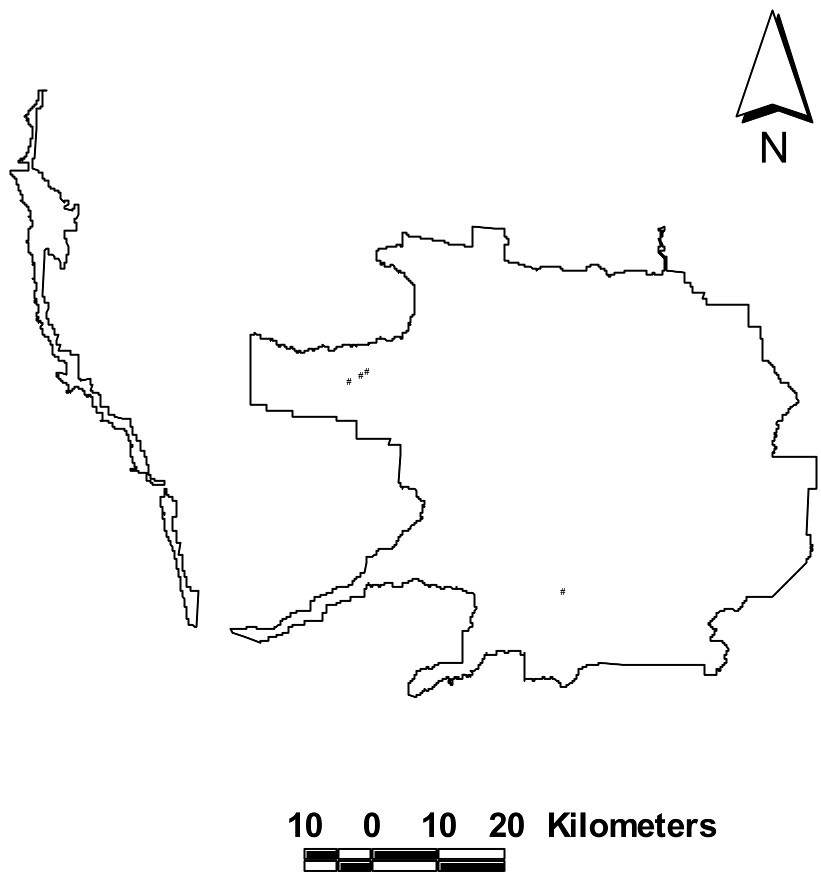
Olympic Torrent Salamander



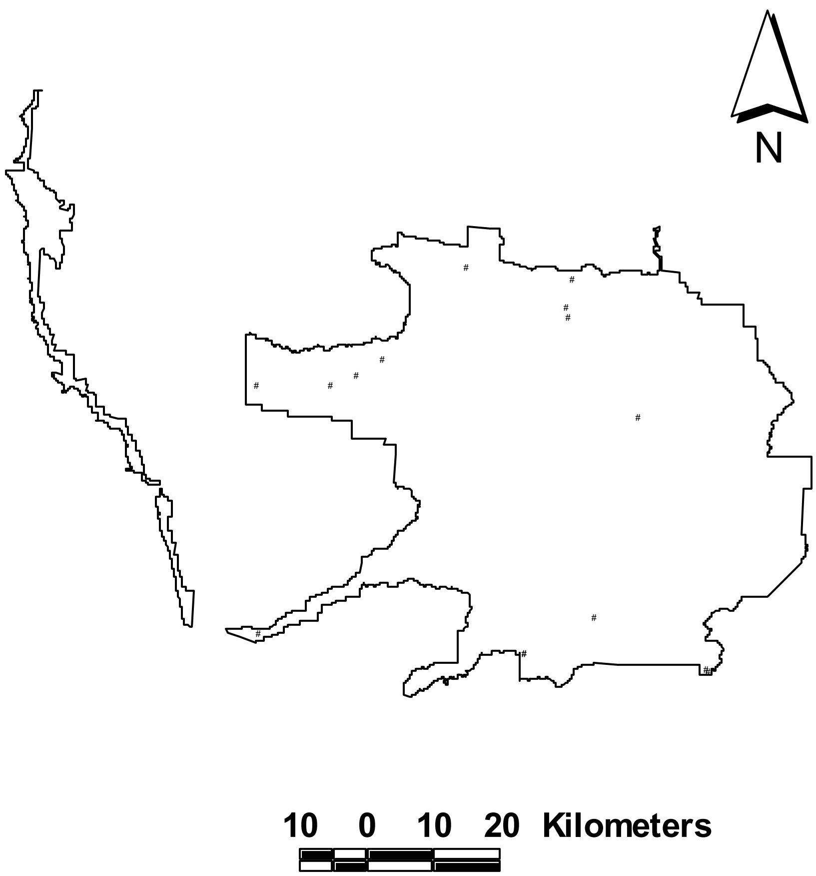
Red-Legged Frog



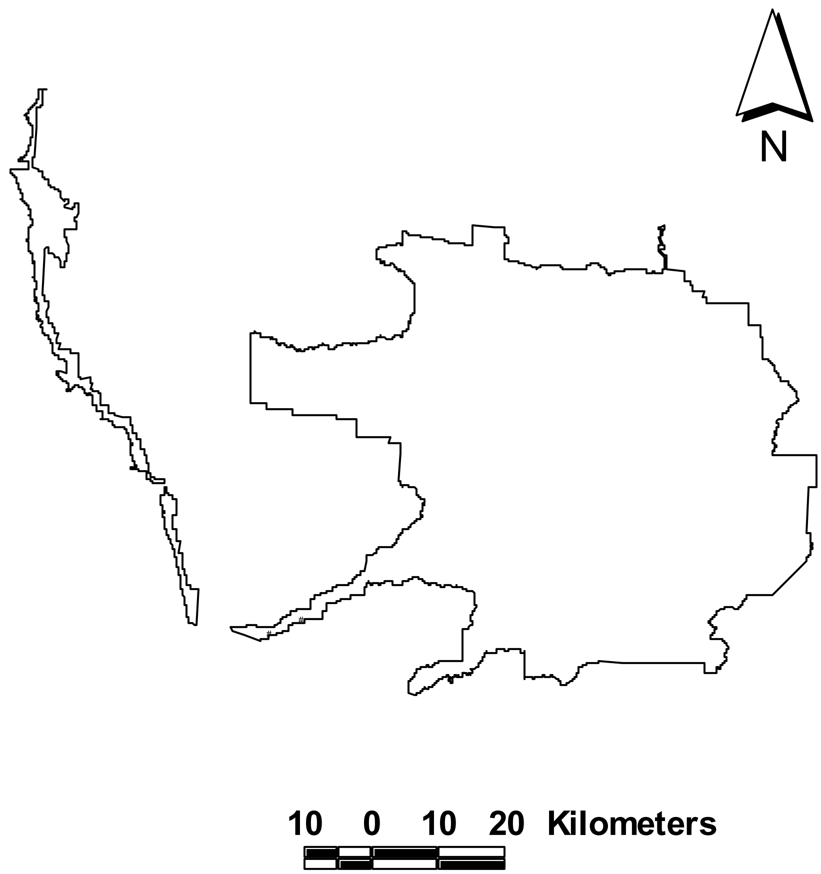
Van Dyke's Salamander



Western Red-backed Salamander



Western Toad



APPENDIX E. LOCATIONS OF POND SURVEYS

NAME	UTM N	UTM E	DRAINAGE
Appleton #2	5309308	445305	SOLEDUCK
Appleton #3	5309320	445453	SOLEDUCK
Appleton #5	5309258	445366	SOLEDUCK
Casper Lake	5306746	444856	SOLEDUCK
Clear Lake	5307464	441821	SOLEDUCK
Clear Lake a	5307550	441807	SOLEDUCK
Clear Lake b	5307550	441844	SOLEDUCK
Clear Lake c	5307550	441946	SOLEDUCK
Clear Lake d	5307523	441956	SOLEDUCK
Clear Lake e	5307445	441990	SOLEDUCK
Clear Lake f	5307306	441885	SOLEDUCK
Clear Lake g	5307334	441863	SOLEDUCK
Clear Lake h	5307356	441832	SOLEDUCK
Clear Lake I	5307365	441789	SOLEDUCK
Clear Lake j	5307343	441782	SOLEDUCK
Clear Lake k	5307337	441810	SOLEDUCK
Clear Lake l	5307331	441841	SOLEDUCK
Deer Lake	5308284	438569	SOLEDUCK
Fawn Pond	5308360	438417	SOLEDUCK
FJ #301	5268900	474400	SKOKOMISH
FJ #302	5268800	474340	SKOKOMISH
FJ #304	5267340	474240	SKOKOMISH
FJ #304a	5267340	474240	SKOKOMISH
FJ #305	5267340	474480	SKOKOMISH
FJ #305a	5267340	474480	SKOKOMISH
GL #103	5306562	472948	GRAND
GL #104	5305956	472404	GRAND
GL #117	5302872	474255	GRAND
GL #117a	5302872	474255	GRAND
GL #118	5303058	474800	GRAND
GL #121	5302380	473060	GRAND
GL #121a	5302306	473084	GRAND
GL #121b	5302491	473072	GRAND
Heart Lake	5306341	445224	SOLEDUCK
Heart Lake a	5306353	445281	SOLEDUCK
Heart Lake b	5306400	445241	SOLEDUCK
Heart Lake c	5306403	445257	SOLEDUCK
Heart Lake d	5306440	445127	SOLEDUCK
Hoh Lake	5305168	441363	HOH
Hoh Lake a	5305048	441148	HOH
James Pond	5308492	380291	QUILLAYUTE
Long Lake	5307786	442310	SOLEDUCK
Long Lake a	5307554	442390	SOLEDUCK
Long Lake b	5307547	442304	SOLEDUCK
Lunch Lake	5307040	441540	SOLEDUCK
Morganroth Lake	5307306	443077	SOLEDUCK
No Name Lake	5306963	443195	SOLEDUCK
No Name Lake a	5306799	443232	SOLEDUCK
No Name Lake b	5306836	443318	SOLEDUCK
No Name Lake c	5306873	443325	SOLEDUCK
No Name Lake d	5306966	443362	SOLEDUCK
No Name Lake e	5307059	443250	SOLEDUCK
No Name Lake f	5307108	443065	SOLEDUCK
No Name Lake h	5307071	443034	SOLEDUCK
No Name Lake I	5307077	443015	SOLEDUCK
No Name Lake j	5307096	442997	SOLEDUCK
No Name Lake k	5306861	443170	SOLEDUCK
RC #403	5297500	484450	DUNGENESS
RC #403a	5297500	484450	DUNGENESS
RC #407	5296350	483750	DUNGENESS
RC #407a	5296350	483730	DUNGENESS
RC #407b	5296360	483750	DUNGENESS
RC #407c	5296360	483750	DUNGENESS
RC #407d	5296360	483750	DUNGENESS
Round Lake	5307032	441141	SOLEDUCK
Round Lake a	5307032	441141	SOLEDUCK
Round Lake b	5307032	441141	SOLEDUCK
Round Lake c	5307032	441141	SOLEDUCK

NAME	UTM N	UTM E	DRAINAGE
Round Lake d	5307032	441141	SOLEDUCK
Round Lake e	5307032	441141	SOLEDUCK
Round Lake f	5307032	441141	SOLEDUCK
SL #20	5307755	441883	SOLEDUCK
SL #20a	5307838	441819	SOLEDUCK
SL #20b	5307838	441851	SOLEDUCK
SL #20c	5307831	441868	SOLEDUCK
SL #20d	5307831	441906	SOLEDUCK
SL #20e	5307845	441906	SOLEDUCK
SL #20f	5307803	441927	SOLEDUCK
SL #20g	5307685	441861	SOLEDUCK
SL #20h	5307706	441927	SOLEDUCK
SL #20i	5307782	441798	SOLEDUCK
SL #26	5307303	441614	SOLEDUCK
SL #26a	5307337	441556	SOLEDUCK
SL #26b	5307343	441538	SOLEDUCK
Soleduck Lake	5308240	441755	SOLEDUCK
Soleduck Lake a	5308190	441755	SOLEDUCK
Swimming Bear Lake	5306721	446561	SOLEDUCK
TL #223	5272804	445435	QUEETS
TL #224	5272631	445046	QUEETS
TL #225	5272613	444668	QUEETS
TL #225a	5272613	444668	QUEETS
TL #225b	5272613	444668	QUEETS
TL #225c	5272613	444668	QUEETS
TL #225d	5272613	444668	QUEETS
TL #225e	5272551	444773	QUEETS
TL #225f	5272551	444773	QUEETS
TL #228	5271913	445708	N FK QUINALT
UL #502	5275250	483810	HAMMA HAMMA
UL #502a	5275130	483810	HAMMA HAMMA
UL #503	5275320	483680	HAMMA HAMMA
UL #503a	5275300	483680	HAMMA HAMMA
UL #504	5275250	483620	HAMMA HAMMA
UL #504a	5275260	483620	HAMMA HAMMA
UL #504b	5275250	483620	HAMMA HAMMA
UL #506	5274062	482940	HAMMA HAMMA
UL #506a	5274062	482960	HAMMA HAMMA
UL #508	5274310	482690	HAMMA HAMMA
UL #508a	5274310	482690	HAMMA HAMMA
UL #508b	5274310	482690	HAMMA HAMMA
Upper Lena Lake	5275341	484421	HAMMA HAMMA
Upper Lena Lake a	5275341	484421	HAMMA HAMMA
Upper Lena Lake b	5275341	484421	HAMMA HAMMA
Upper Lena Lake c	5275341	484421	HAMMA HAMMA
Upper Lena Lake d	5275341	484421	HAMMA HAMMA
Upper Lena Lake e	5275341	484421	HAMMA HAMMA
Y Lake #31	5306754	442268	SOLEDUCK
Y Lake #35	5306684	442149	SOLEDUCK
Y Lake #35a	5306629	442156	SOLEDUCK
Y Lake #37	5306598	442910	SOLEDUCK
Y Lake #37a	5306771	442849	SOLEDUCK
Y Lake #37b	5306697	442885	SOLEDUCK
Y Lake #38	5306573	442489	SOLEDUCK
Y Lake #39	5306558	442611	SOLEDUCK
Y Lake #41	5306511	442042	SOLEDUCK
Y Lake #41a	5306511	442042	SOLEDUCK
Y Lake #43	5306486	442174	SOLEDUCK
Y Lake #43a	5306486	442174	SOLEDUCK
Y Lake #44	5306474	442686	SOLEDUCK
Y Lake #46	5306443	442236	SOLEDUCK
Y Lake #48	5306431	442366	SOLEDUCK
Y Lake #49	5306400	442576	SOLEDUCK
Y Lake #51	5306434	442865	SOLEDUCK
Y Lake #56	5306282	442947	SOLEDUCK

APPENDIX F. SUMMARY OF AMPHIBIAN DETECTIONS FOR POND AMPHIBIAN SURVEYS

In the following table, a 1 was entered if only adults or juveniles of a species was detected and a 2 was entered if eggs, larvae, or paedomorphs were detected. If a species of amphibian was not detected, a zero was entered. Pond locations can be found in Appendix E.

NAME	AMGR	AMMA	BUBO	HYRE	RAAU	RACA	TAGR
Appleton #2	2	0	0	0	0	1	1
Appleton #3	0	0	0	0	0	1	0
Appleton #5	0	0	0	0	0	1	0
Casper Lake	2	2	0	0	0	1	0
Clear Lake	2	2	0	0	0	1	1
Clear Lake a	2	0	0	0	0	2	0
Clear Lake b	2	0	0	0	0	2	0
Clear Lake c	0	0	0	0	0	2	0
Clear Lake d	2	1	0	0	0	2	0
Clear Lake e	0	0	0	0	0	2	0
Clear Lake f	2	2	0	0	0	2	0
Clear Lake g	0	0	0	0	0	2	0
Clear Lake h	0	0	0	0	0	1	0
Clear Lake I	0	0	0	0	0	0	0
Clear Lake j	2	0	0	0	0	2	0
Clear Lake k	0	0	0	0	0	2	0
Clear Lake l	2	0	0	0	0	0	0
Deer Lake	0	0	2	0	0	2	0
Fawn Pond	2	0	2	0	0	2	0
FJ #301	2	0	0	0	0	2	0
FJ #302	2	0	0	0	0	1	0
FJ #304	2	0	0	0	0	0	0
FJ #304a	0	0	0	0	0	0	0
FJ #305	0	0	0	0	0	1	0
FJ #305a	0	0	0	0	0	0	0
GL #103	0	0	0	0	0	2	0
GL #104	0	2	0	0	0	1	0
GL #117	0	2	0	0	0	2	0
GL #117a	0	0	0	0	0	1	0
GL #118	0	2	0	0	0	2	0
GL #121	0	2	0	0	0	2	0
GL #121a	0	0	0	0	0	0	0
GL #121b	0	0	0	0	0	2	0
Heart Lake	2	2	0	0	0	2	0
Heart Lake a	0	0	0	0	0	1	0
Heart Lake b	0	0	0	0	0	2	0
Heart Lake c	0	0	0	0	0	1	0
Heart Lake d	0	0	0	0	0	2	0
Hoh Lake	0	0	2	0	0	0	0
Hoh Lake a	0	0	0	0	0	0	0
James Pond	2	0	0	0	2	0	0
Long Lake	0	0	0	0	0	1	0
Long Lake a	0	0	0	0	0	0	0
Long Lake b	0	0	0	0	0	1	0
Lunch Lake	0	0	0	0	0	1	0
Morganroth Lake	2	0	0	0	0	1	0
No Name Lake	2	0	0	0	0	1	0
No Name Lake a	0	0	0	0	0	1	0
No Name Lake b	0	0	0	0	0	2	0
No Name Lake c	0	0	0	0	0	1	0
No Name Lake d	2	0	0	0	0	2	0
No Name Lake e	2	2	0	0	0	2	0
No Name Lake f	0	0	0	0	0	1	0
No Name Lake h	2	0	0	0	0	2	0
No Name Lake I	0	0	0	0	0	2	0
No Name Lake j	0	1	0	0	0	2	0
No Name Lake k	0	1	0	0	0	2	0
RC #403	0	0	0	0	0	2	0
RC #403a	0	0	0	0	0	2	0
RC #407	0	2	0	0	0	1	0
RC #407a	0	0	0	0	0	2	0
RC #407b	0	0	0	0	0	1	0
RC #407c	0	0	0	0	0	1	0
RC #407d	0	0	0	0	0	0	0

NAME	AMGR	AMMA	BUBO	HYRE	RAAU	RACA	TAGR
Round Lake	0	0	0	0	0	1	0
Round Lake a	0	0	0	0	0	0	0
Round Lake b	0	0	0	0	0	0	0
Round Lake c	0	0	0	0	0	1	0
Round Lake d	0	0	0	0	0	0	0
Round Lake e	0	0	0	0	0	0	0
Round Lake f	0	0	0	0	0	1	0
SL #20	0	0	0	0	0	0	0
SL #20a	0	0	0	0	0	0	0
SL #20b	0	0	0	0	0	0	0
SL #20c	0	0	0	0	0	0	0
SL #20d	0	0	0	0	0	0	0
SL #20e	0	0	0	0	0	0	0
SL #20f	0	0	0	0	0	0	0
SL #20g	0	0	0	0	0	0	0
SL #20h	0	0	0	0	0	0	0
SL #20i	0	0	0	0	0	0	0
SL #26	0	0	0	0	0	2	0
SL #26a	0	2	0	0	0	2	0
SL #26b	0	2	0	0	0	2	0
Soleduck Lake	0	0	0	0	0	1	0
Soleduck Lake a	0	0	0	0	0	0	0
Swimming Bear Lake	0	2	0	0	0	2	0
TL #223	2	0	0	0	0	2	1
TL #224	2	0	0	0	0	2	0
TL #225	2	0	0	0	0	2	0
TL #225a	0	0	0	0	0	0	0
TL #225b	0	0	0	0	0	0	0
TL #225c	0	0	0	0	0	1	0
TL #225d	0	0	0	0	0	1	0
TL #225e	2	0	0	2	0	1	1
TL #225f	0	0	0	0	0	1	0
TL #228	2	0	0	2	0	2	0
UL #502	2	0	0	0	0	1	0
UL #502a	0	0	0	0	0	2	0
UL #503	0	1	0	0	0	2	0
UL #503a	2	2	0	0	0	1	0
UL #504	0	0	0	0	0	2	0
UL #504a	0	2	0	0	0	2	0
UL #504b	0	0	0	0	0	1	0
UL #506	2	0	0	0	0	1	0
UL #506a	0	2	0	0	0	2	0
UL #508	0	2	0	0	0	1	0
UL #508a	0	2	0	0	0	1	0
UL #508b	0	0	0	0	0	1	0
Upper Lena Lake	2	0	0	1	0	1	0
Upper Lena Lake a	0	0	0	0	0	0	0
Upper Lena Lake b	0	0	0	0	0	1	0
Upper Lena Lake c	0	0	0	0	0	0	0
Upper Lena Lake d	0	0	0	0	0	0	0
Upper Lena Lake e	0	0	0	0	0	0	0
Y Lake #31	0	0	0	0	0	0	0
Y Lake #35	0	2	0	0	0	0	0
Y Lake #35a	0	0	0	0	0	0	0
Y Lake #37	0	2	0	0	0	0	0
Y Lake #37a	0	0	0	0	0	0	0
Y Lake #37b	0	0	0	0	0	0	0
Y Lake #38	0	2	0	0	0	0	0
Y Lake #39	2	2	0	0	0	0	0
Y Lake #41	0	1	0	0	0	0	0
Y Lake #41a	0	1	0	0	0	0	0
Y Lake #43	0	2	0	0	0	0	0
Y Lake #43a	0	0	0	0	0	0	0
Y Lake #44	0	1	0	0	0	2	0
Y Lake #46	0	2	0	0	0	0	0
Y Lake #48	0	2	0	0	0	0	0
Y Lake #49	2	1	0	0	0	1	0
Y Lake #51	0	0	0	0	0	2	0
Y Lake #56	2	2	0	0	0	2	0

APPENDIX G. MAPS OF POND SURVEY LOCATIONS.

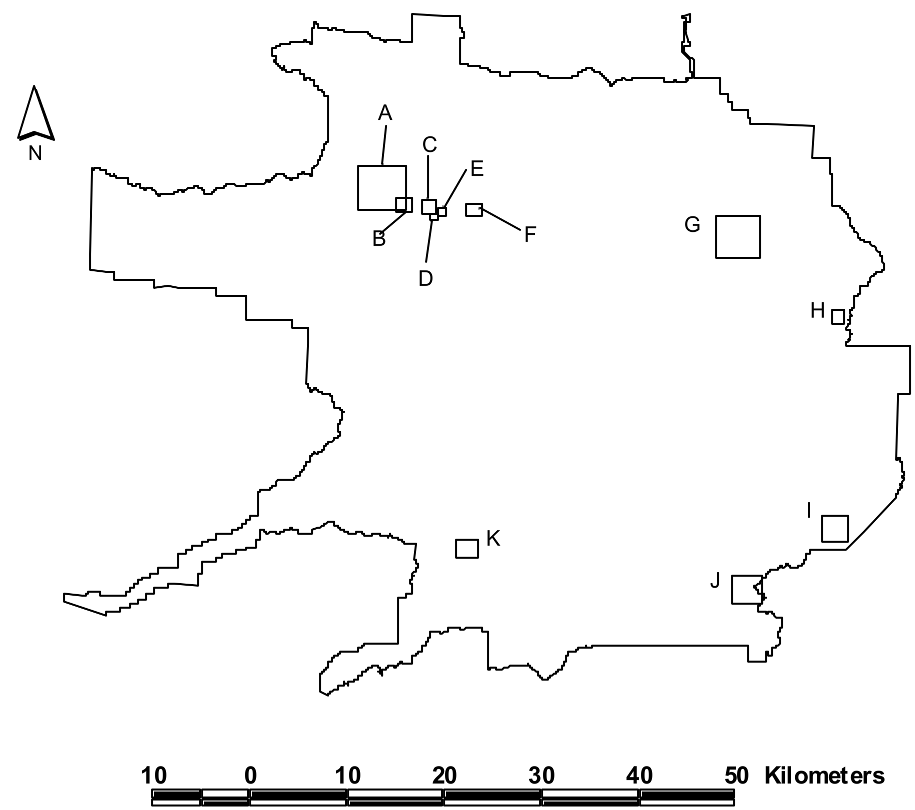
The following maps are for 11 clusters of ponds that were surveyed for amphibians between 1996 and 1998:

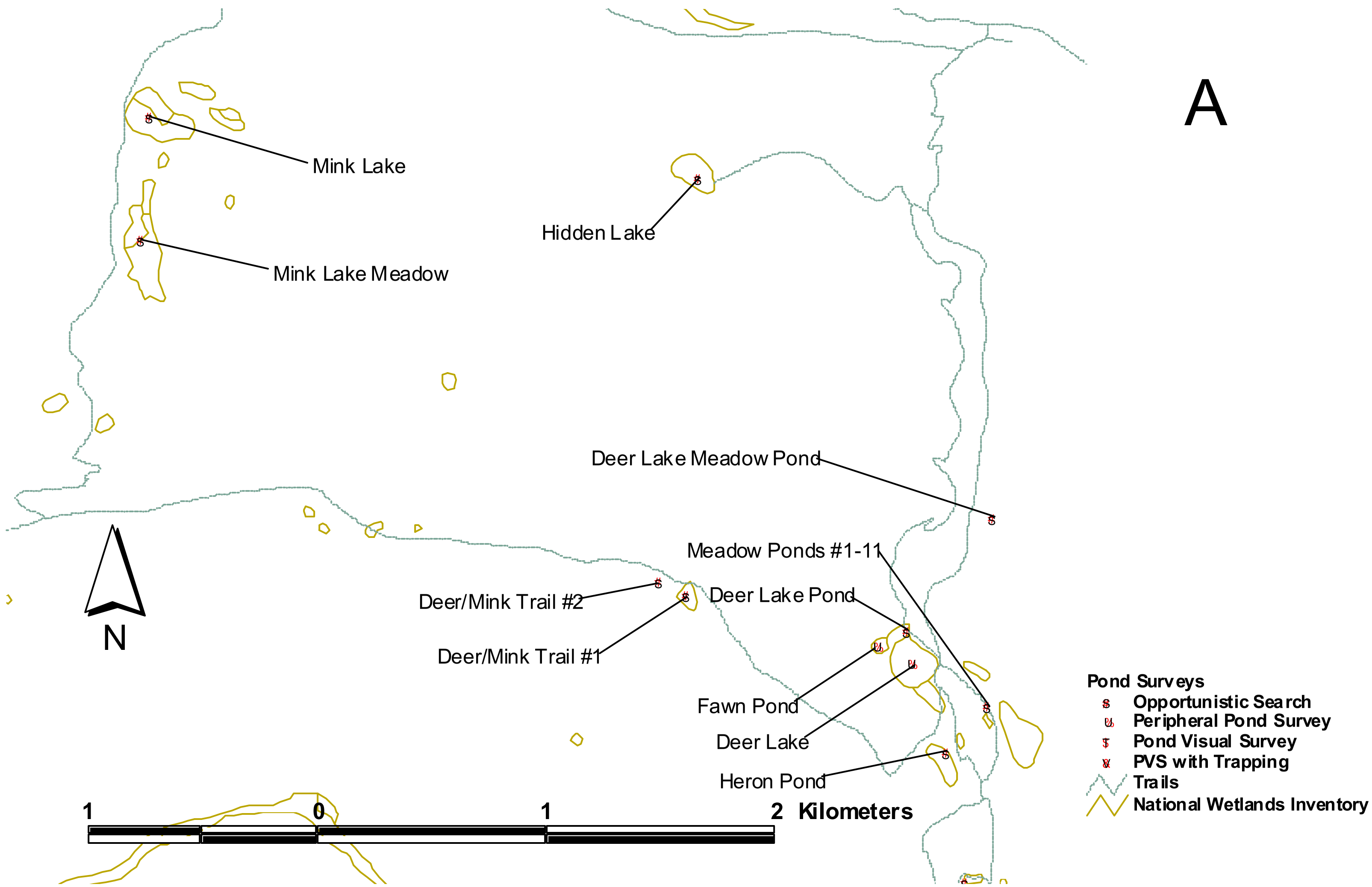
A. Mink and Deer Lakes.
B. Potholes Ponds.

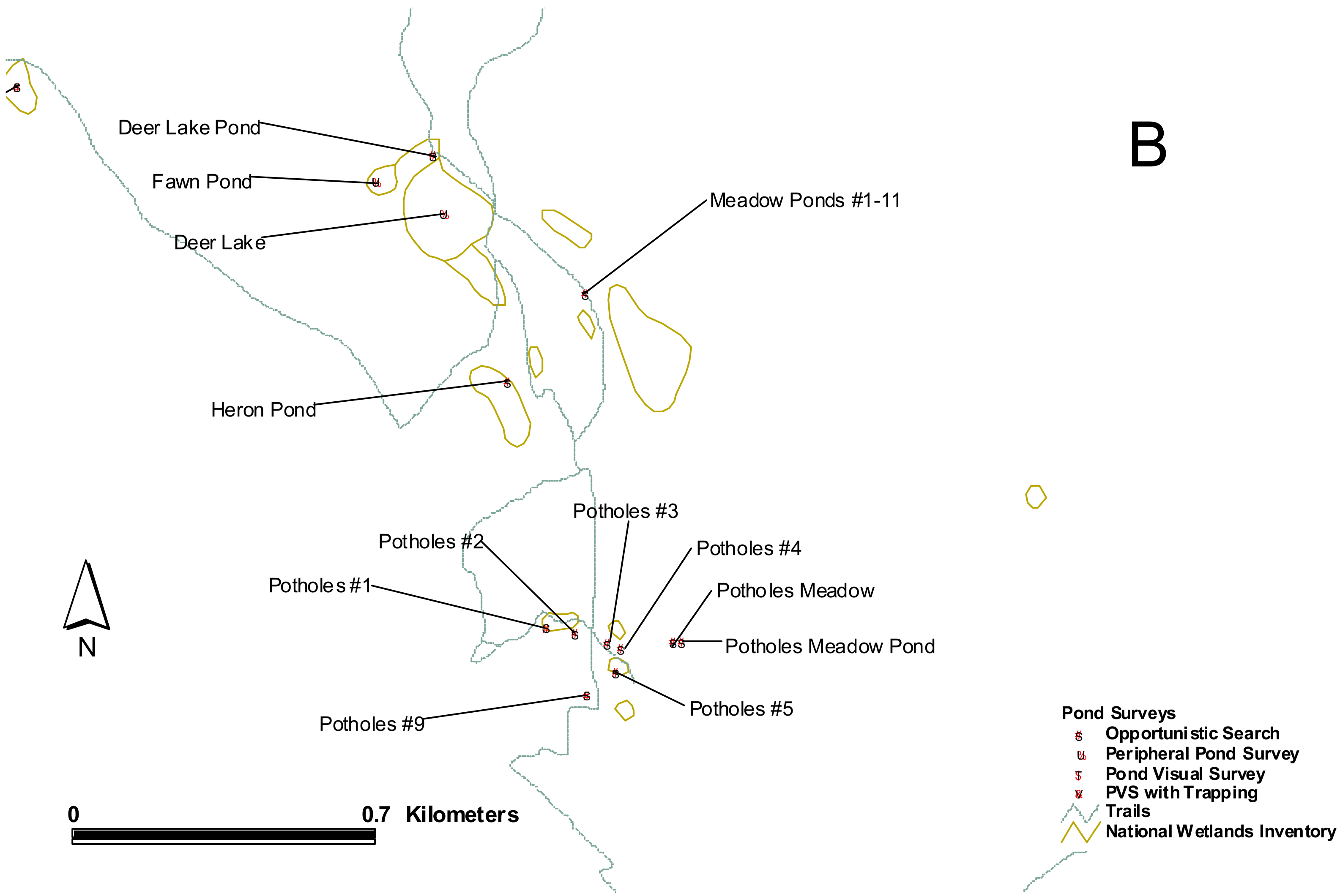
“Seven Lakes Cluster”:
C. Seven Lakes.
D. Y Lakes.
E. Morganroth Lake.
F. Swimming Bear Lake.

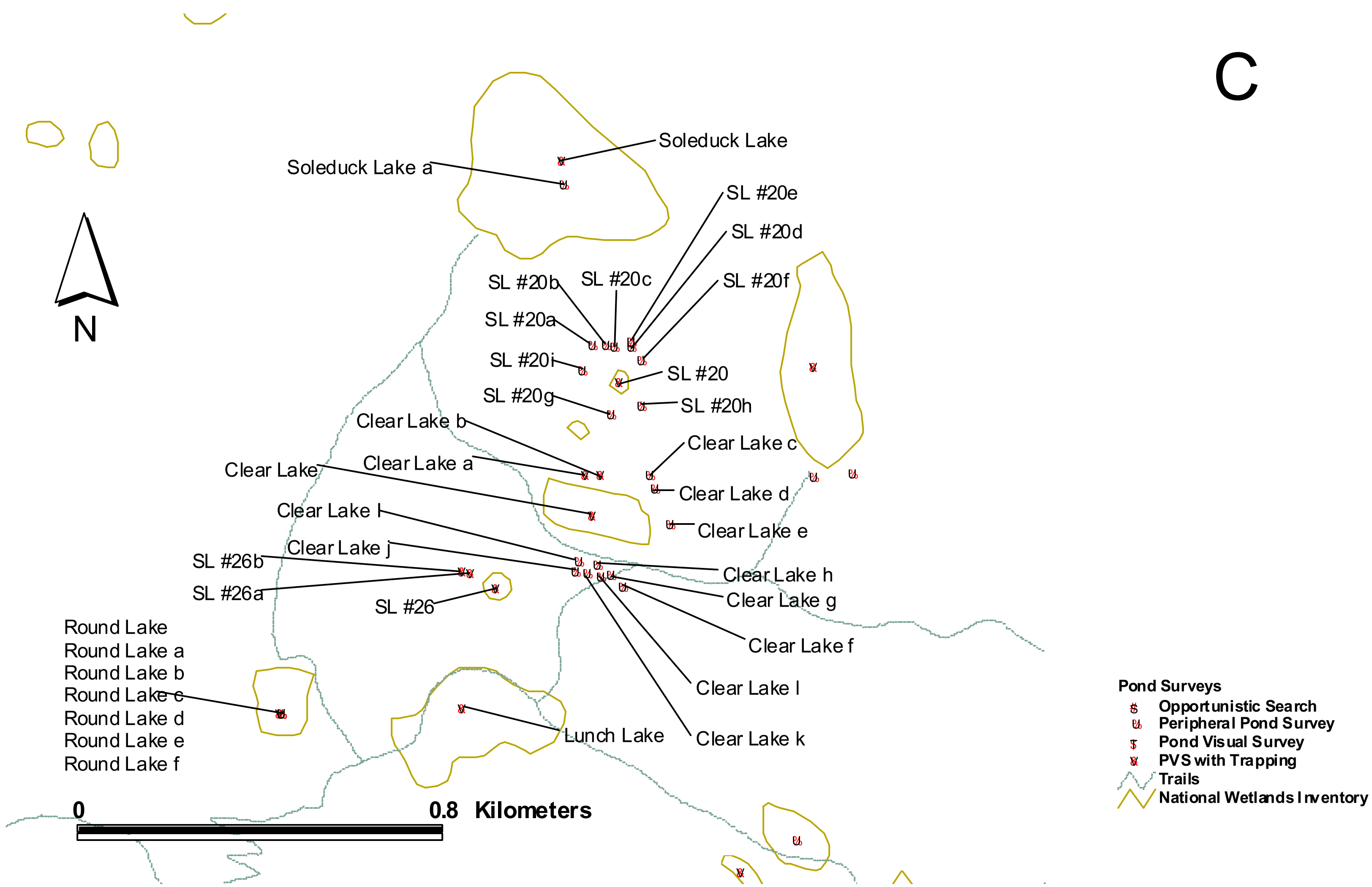
G. Grand Lake.
H. Royal Creek.
I. Lena Lakes.
J. Flapjack Lakes.
K. Three Lakes.

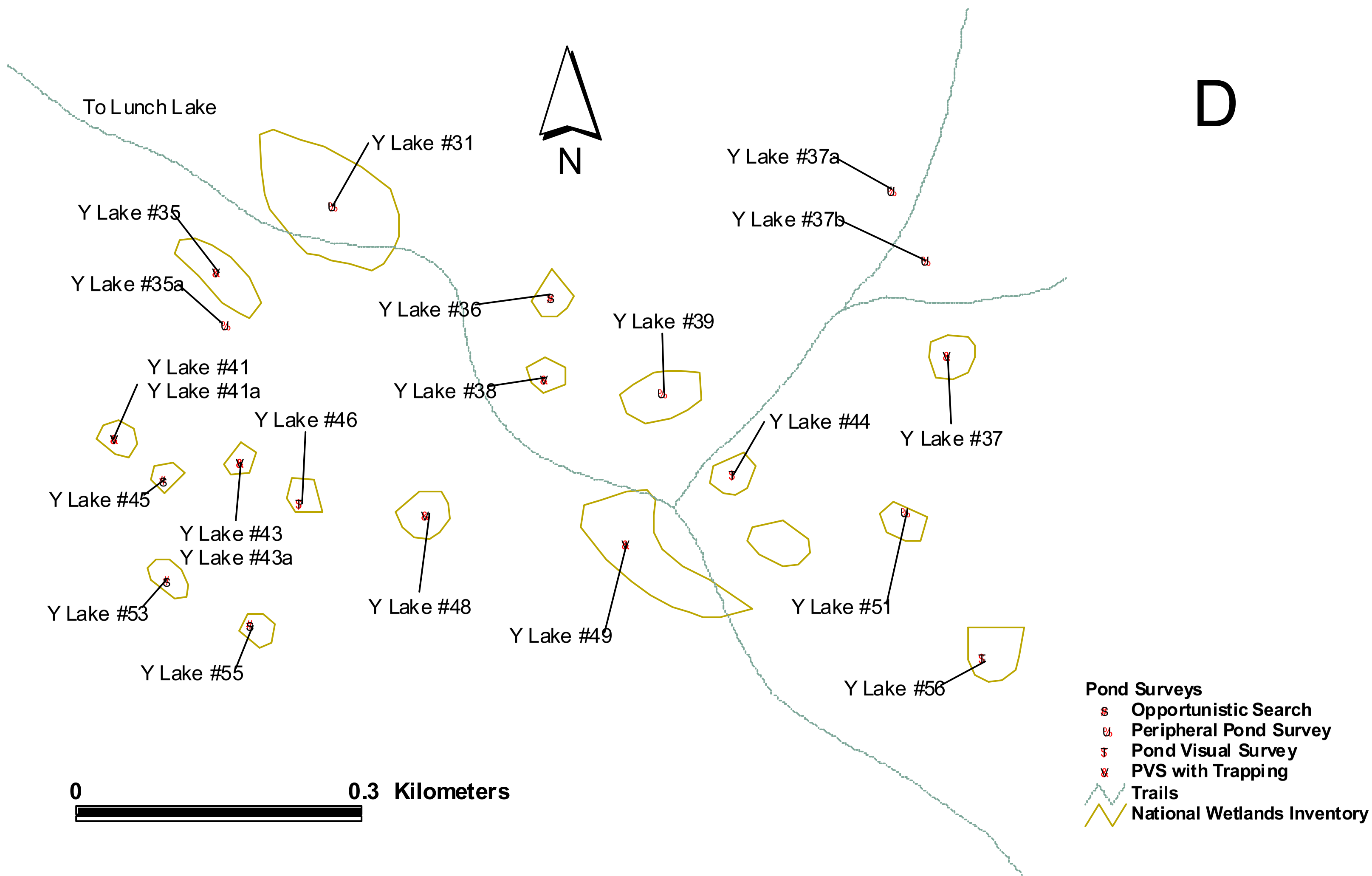
The first map (on the next page) is a locator map.


N
A
B
C
D
E
F
G
H
I
J
K
10 0 10 20 30 40 50 Kilometers

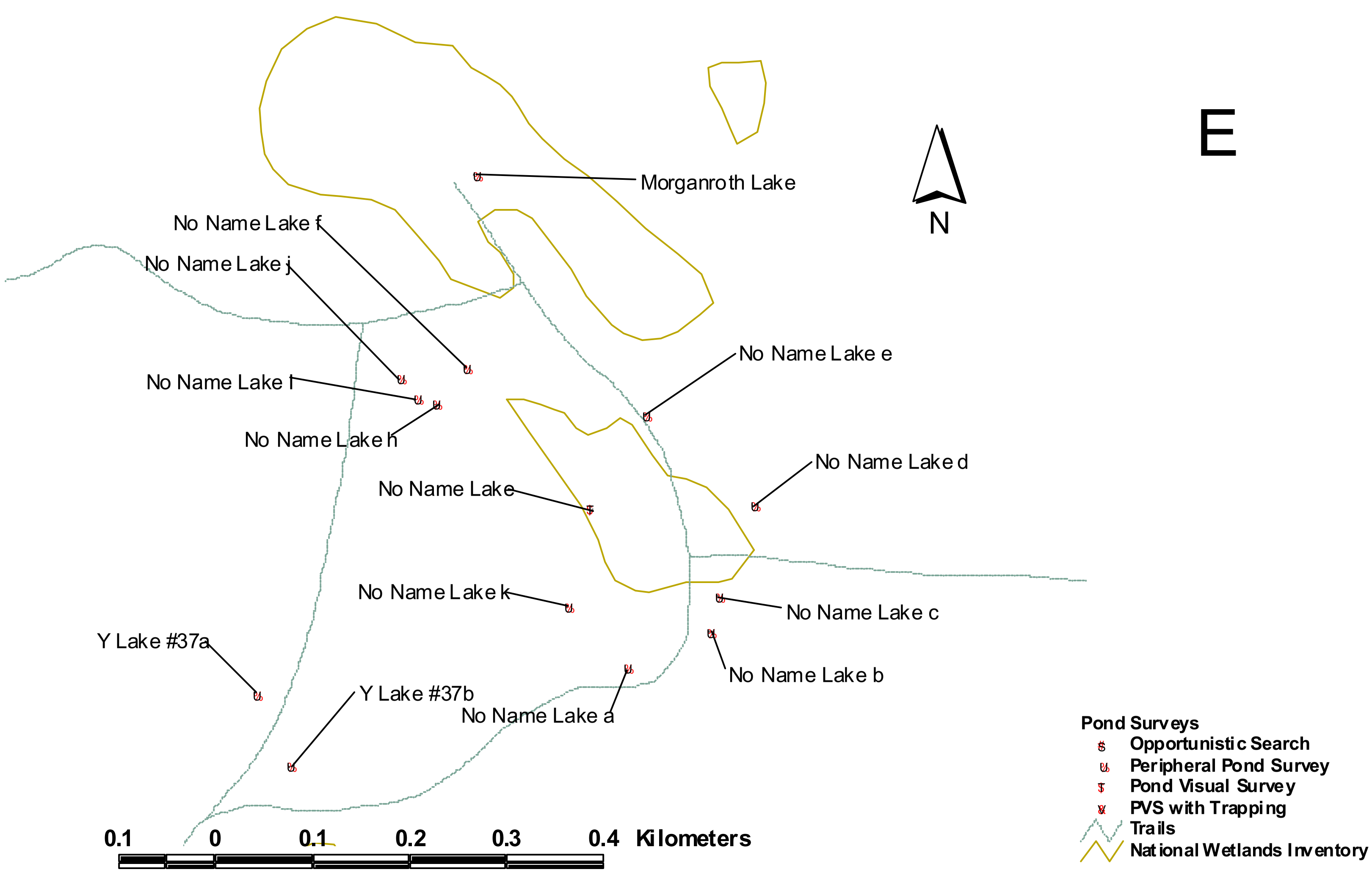

A
Mink Lake
Mink Lake Meadow
Hidden Lake
Deer Lake Meadow Pond
Meadow Ponds #1-11
Deer/Mink Trail #2
Deer Lake Pond
Deer/Mink Trail #1
Fawn Pond
Deer Lake
Heron Pond
N
1
0
1
2 Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory

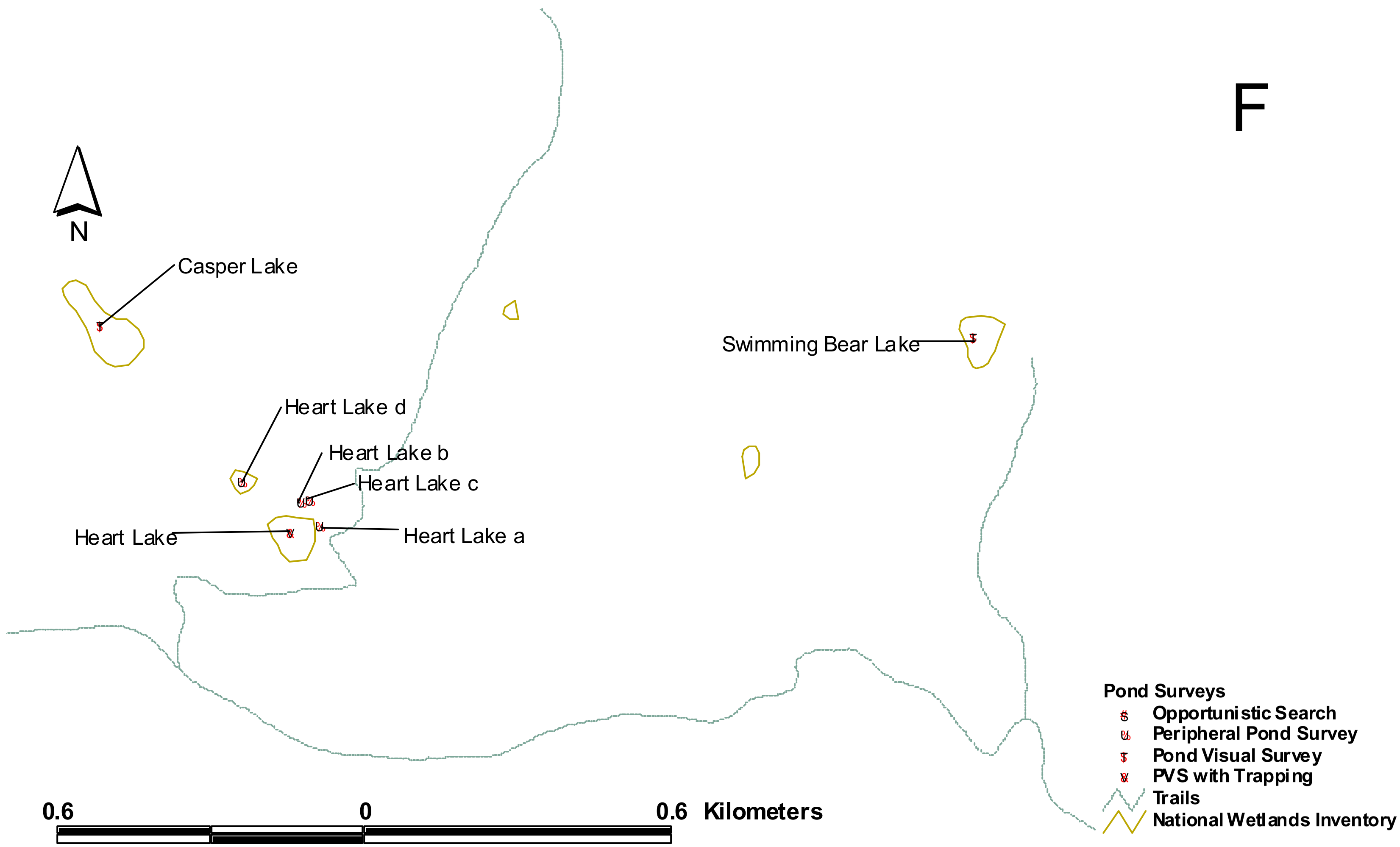

B
Deer Lake Pond
Fawn Pond
Deer Lake
Meadow Ponds #1-11
Heron Pond
Potholes #3
Potholes #2
Potholes #4
Potholes #1
Potholes Meadow
Potholes Meadow Pond
Potholes #5
Potholes #9
N
0
0.7 Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory

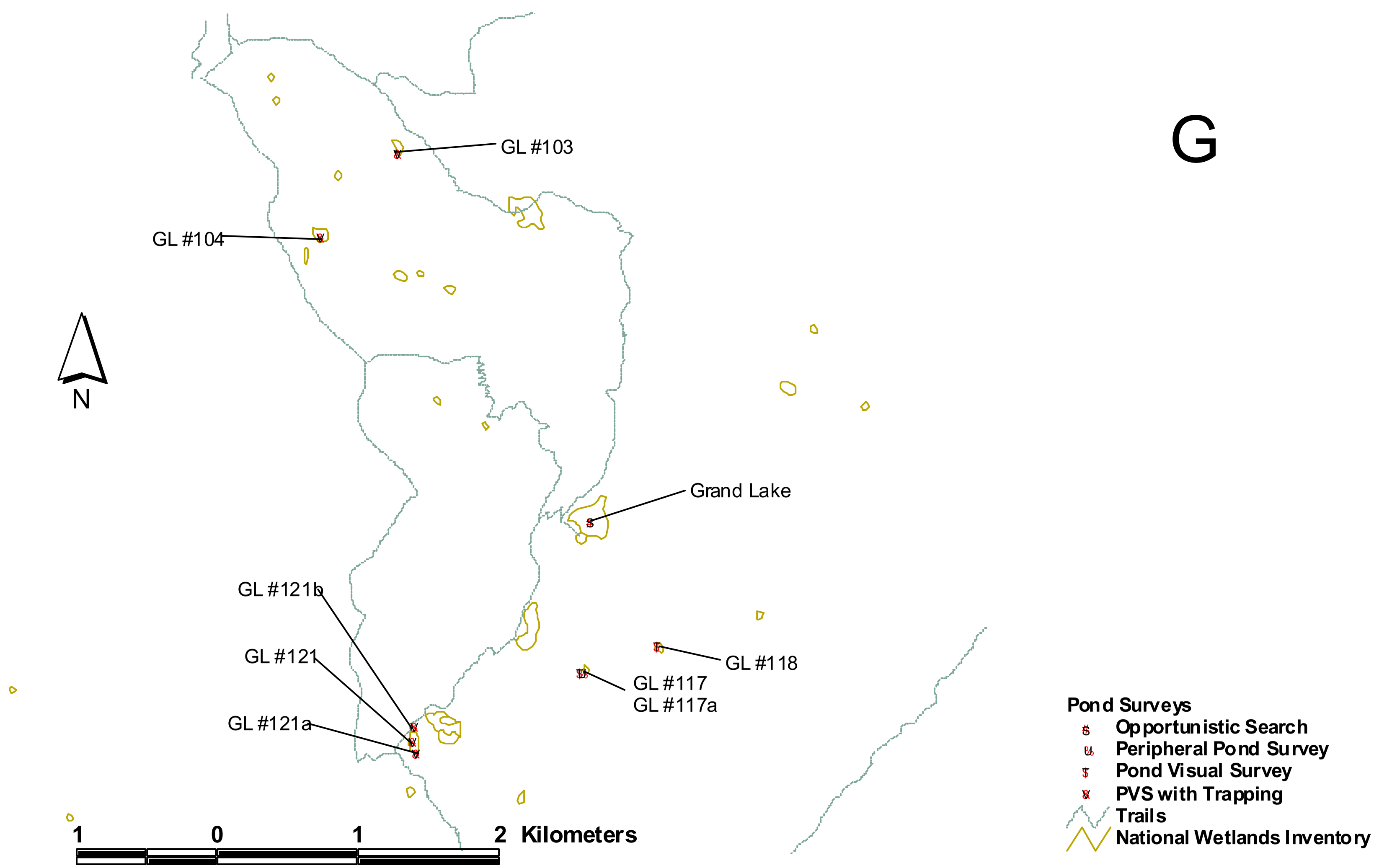

C
N
Soleduck Lake
Soleduck Lake a
SL #20e
SL #20d
SL #20f
SL #20b
SL #20c
SL #20a
SL #20i
SL #20
SL #20g
SL #20h
Clear Lake b
Clear Lake c
Clear Lake
Clear Lake a
Clear Lake d
Clear Lake I
Clear Lake e
Clear Lake j
Clear Lake h
SL #26b
Clear Lake g
SL #26a
SL #26
Clear Lake f
Round Lake
Round Lake a
Round Lake b
Round Lake c
Round Lake d
Round Lake e
Round Lake f
Clear Lake l
Lunch Lake
Clear Lake k
0
0.8 Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory

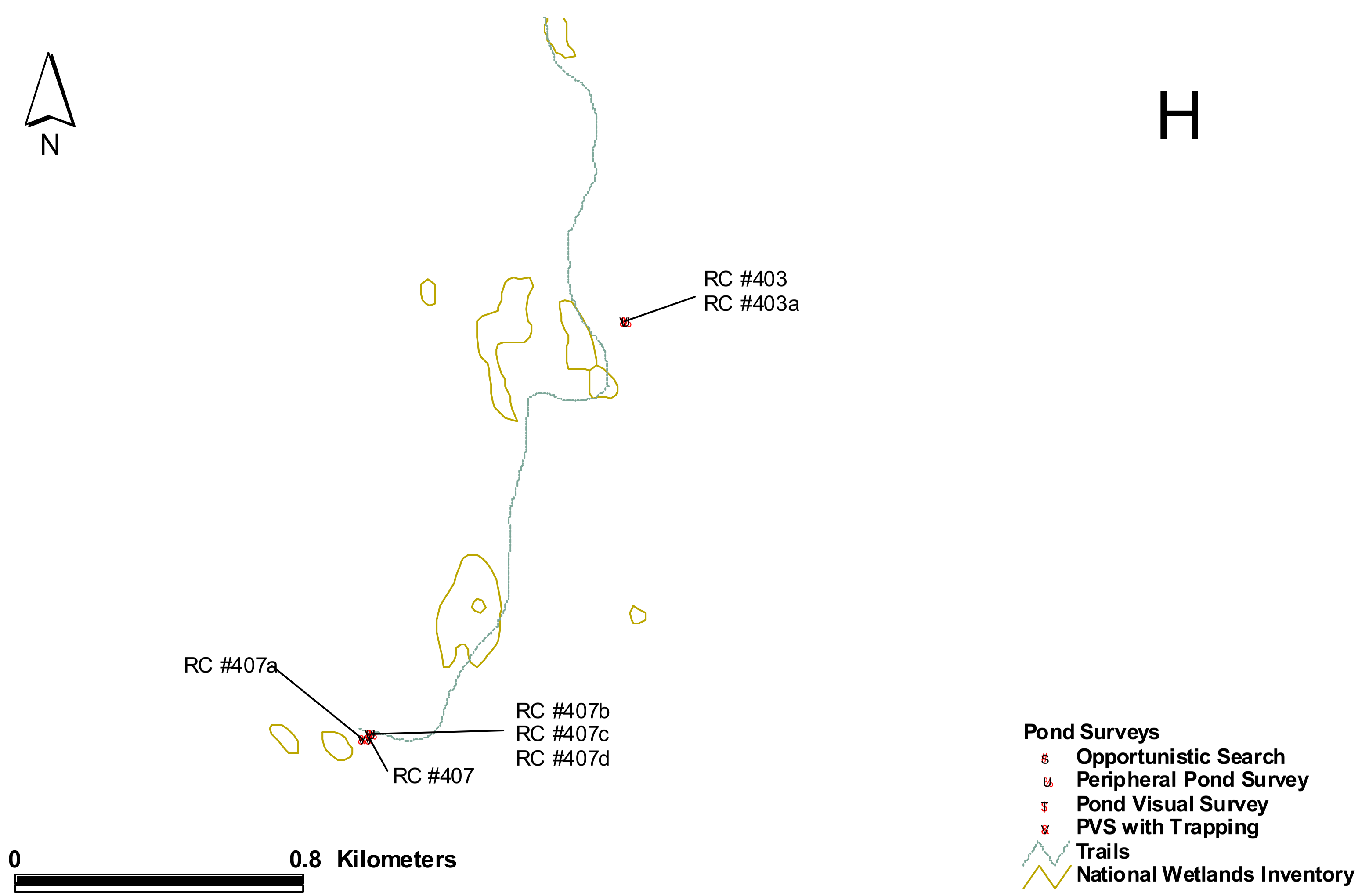

D
N
To Lunch Lake
Y Lake #31
Y Lake #35
Y Lake #35a
Y Lake #36
Y Lake #37a
Y Lake #37b
Y Lake #37
Y Lake #38
Y Lake #39
Y Lake #41
Y Lake #41a
Y Lake #43
Y Lake #43a
Y Lake #44
Y Lake #45
Y Lake #46
Y Lake #48
Y Lake #49
Y Lake #51
Y Lake #53
Y Lake #55
Y Lake #56
0
0.3 Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory

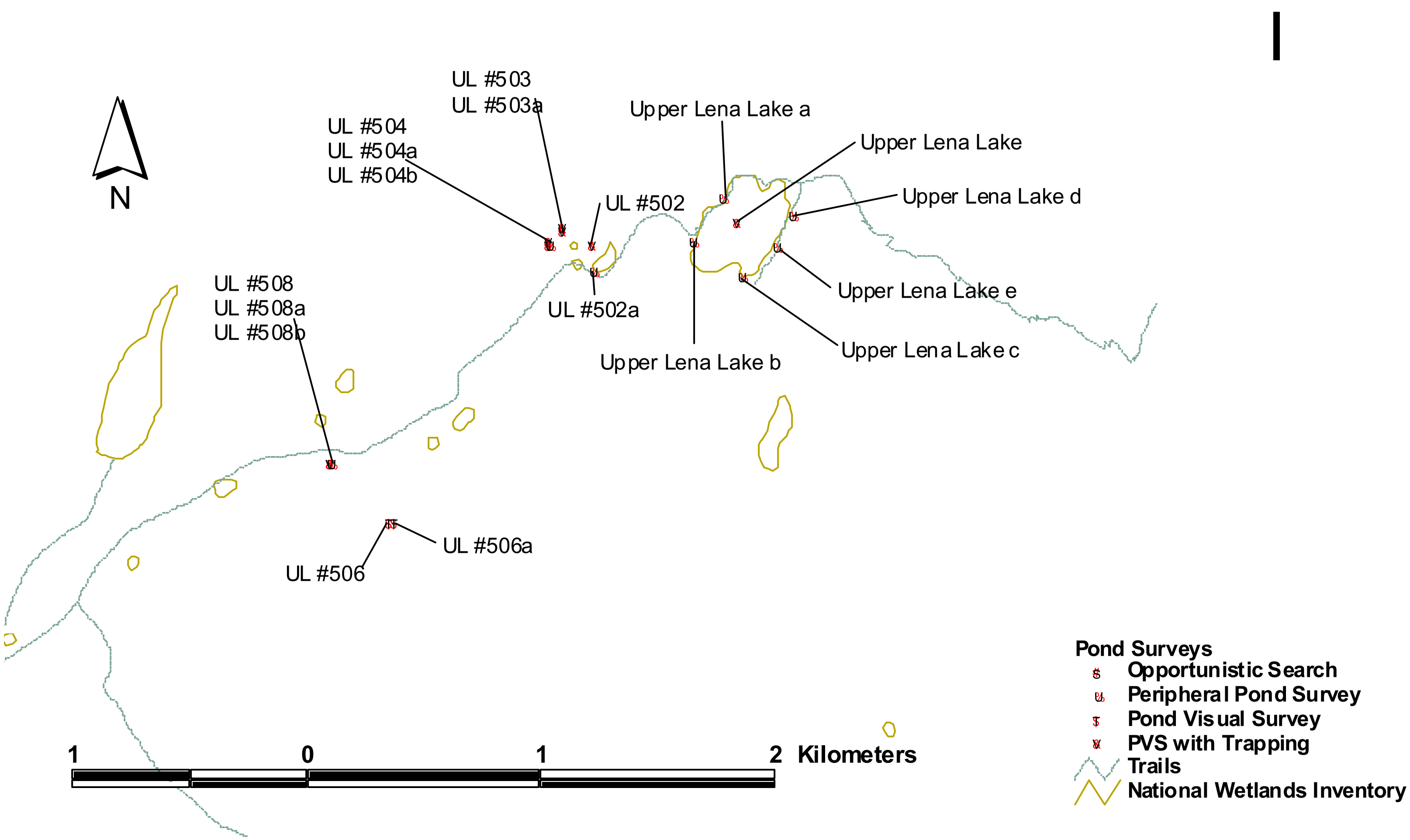
E

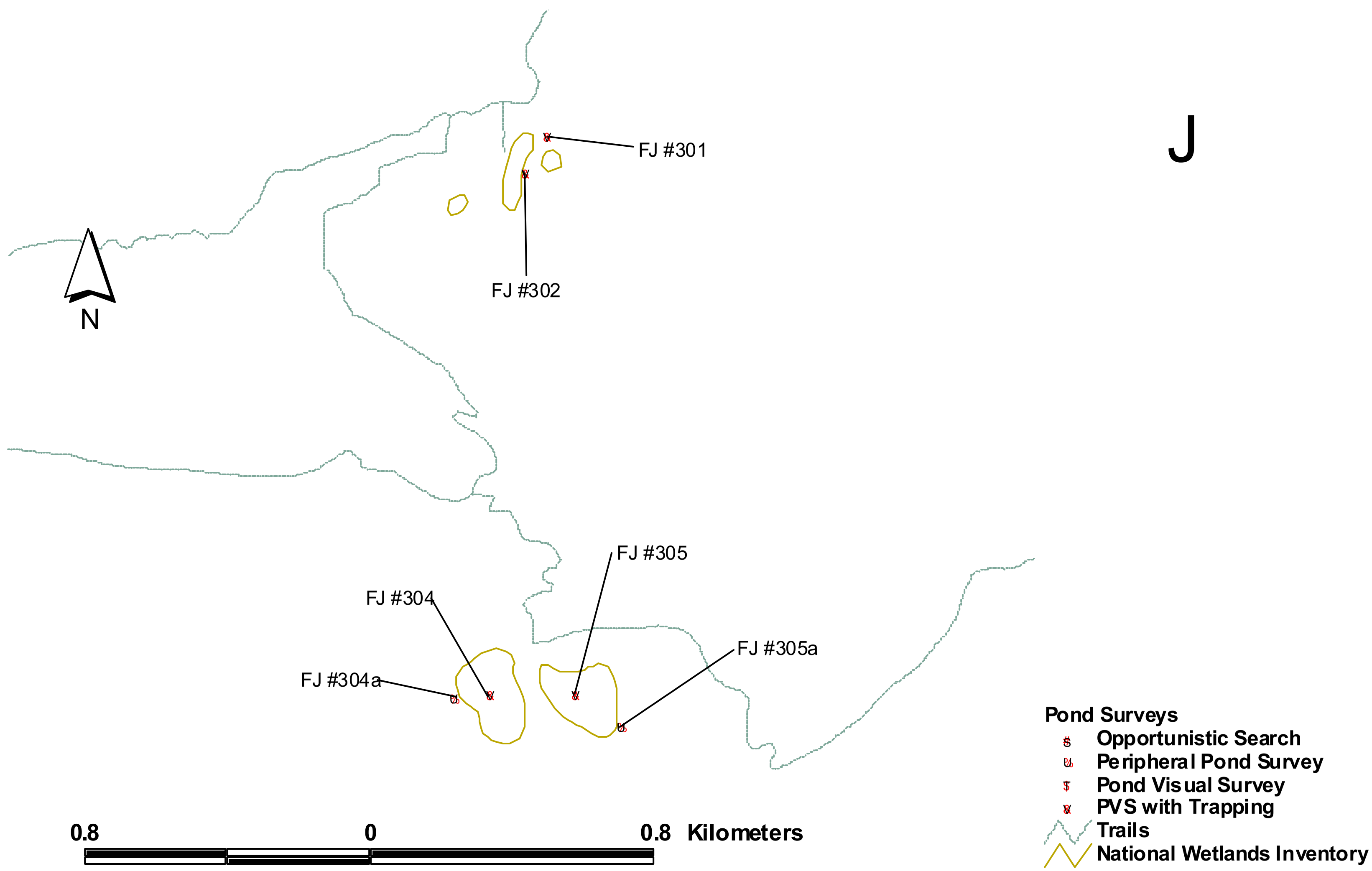

N
Morganroth Lake
No Name Lake f
No Name Lake j
No Name Lake l
No Name Lake h
No Name Lake
No Name Lake e
No Name Lake d
No Name Lake k
No Name Lake c
No Name Lake b
No Name Lake a
Y Lake #37a
Y Lake #37b
0.1 0 0.1 0.2 0.3 0.4 Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory

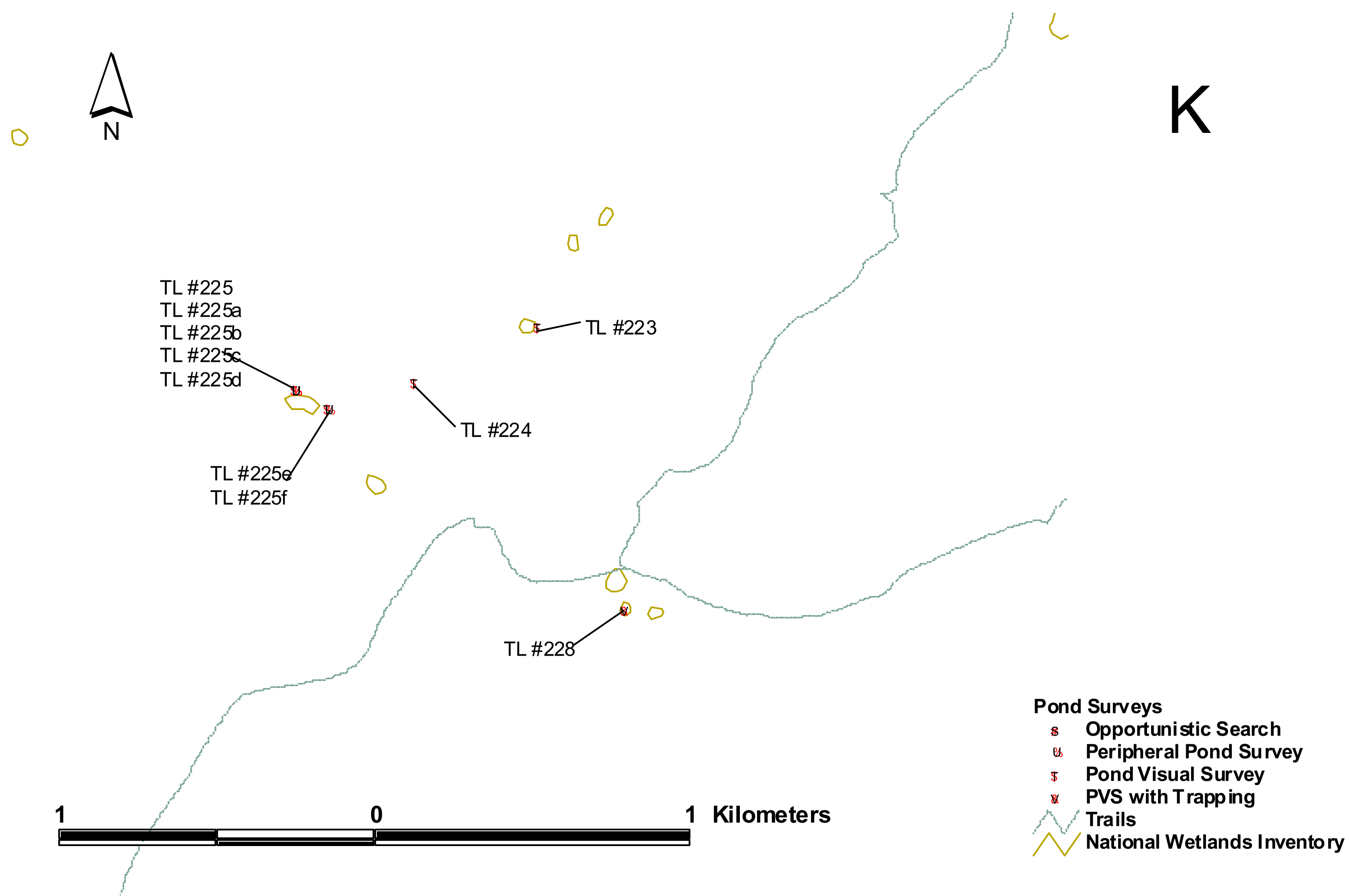

F
N
Casper Lake
Heart Lake d
Heart Lake b
Heart Lake c
Heart Lake
Heart Lake a
Swimming Bear Lake
0.6
0
0.6 Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory


G
GL #103
GL #104
N
Grand Lake
GL #121b
GL #121
GL #121a
GL #118
GL #117
GL #117a
1 0 1 2 Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory


H
N
RC #403
RC #403a
RC #407a
RC #407b
RC #407c
RC #407d
RC #407
0
0.8 Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory


N
UL #503
UL #503a
UL #504
UL #504a
UL #504b
Upper Lena Lake a
Upper Lena Lake
Upper Lena Lake d
UL #502
UL #502a
Upper Lena Lake e
Upper Lena Lake c
Upper Lena Lake b
UL #508
UL #508a
UL #508b
UL #506a
UL #506
1
0
1
2
Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory


J
FJ #301
FJ #302
N
FJ #305
FJ #304
FJ #305a
FJ #304a
0.8
0
0.8 Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory



K
N
TL #223
TL #224
TL #225
TL #225a
TL #225b
TL #225c
TL #225d
TL #225e
TL #225f
TL #228
1
0
1
Kilometers
Pond Surveys
Opportunistic Search
Peripheral Pond Survey
Pond Visual Survey
PVS with Trapping
Trails
National Wetlands Inventory

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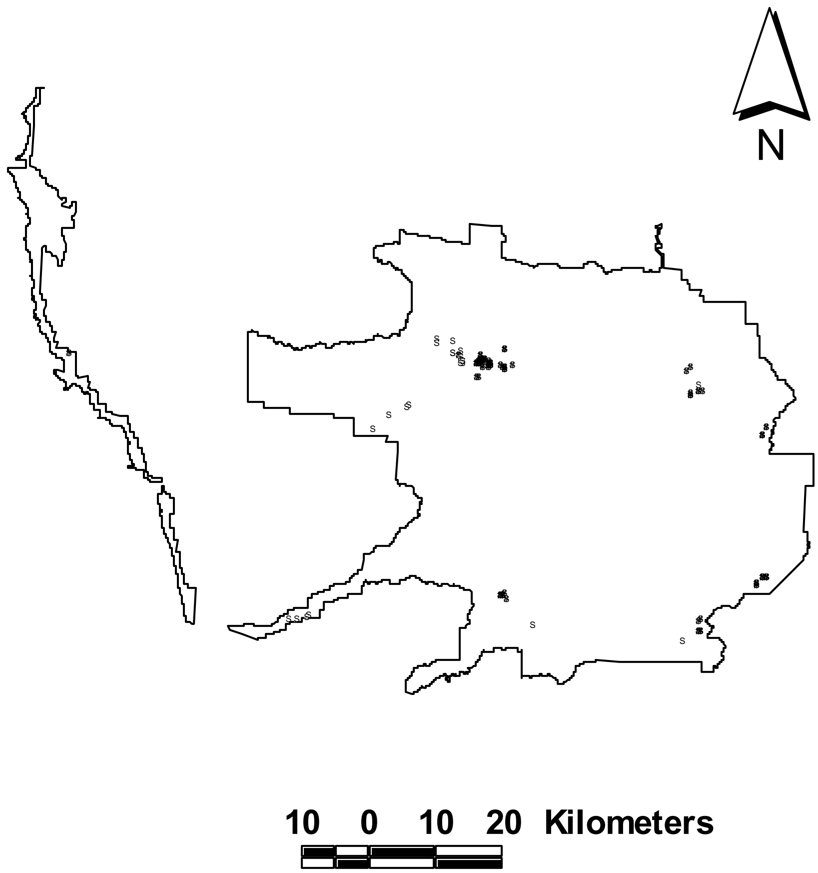
APPENDIX H. MAPS OF AMPHIBIAN DETECTIONS IN PONDS

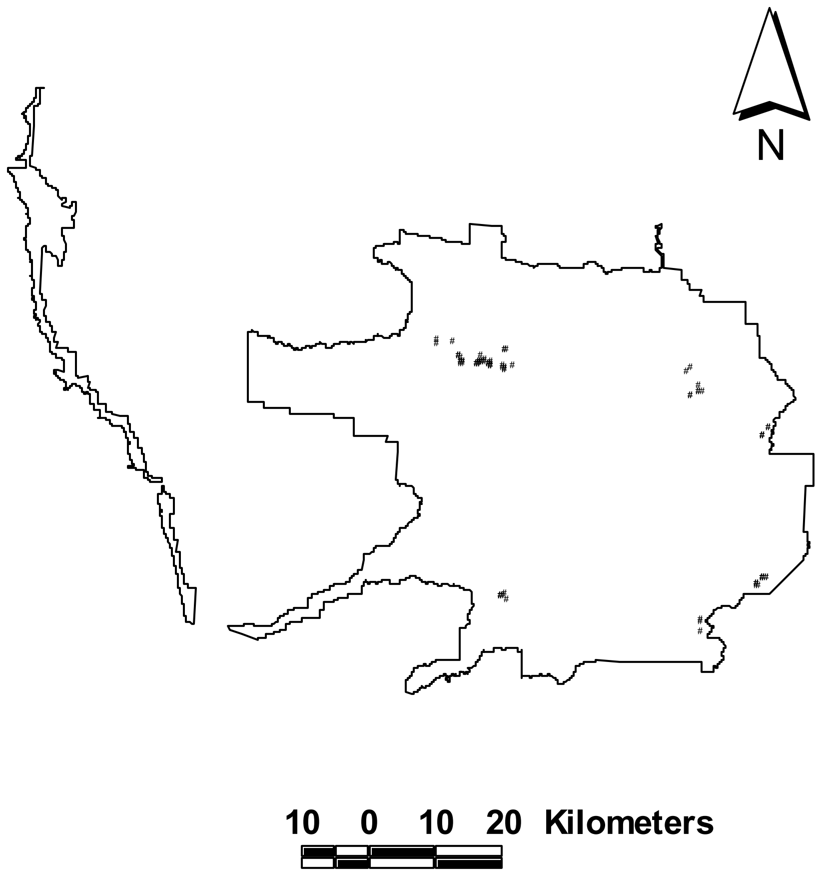
The following series of maps show the locations of amphibian detections in ponds in Olympic National Park. Map 1 shows the location of all pond surveys. Subsequent maps show amphibian detections.

Pond Surveys

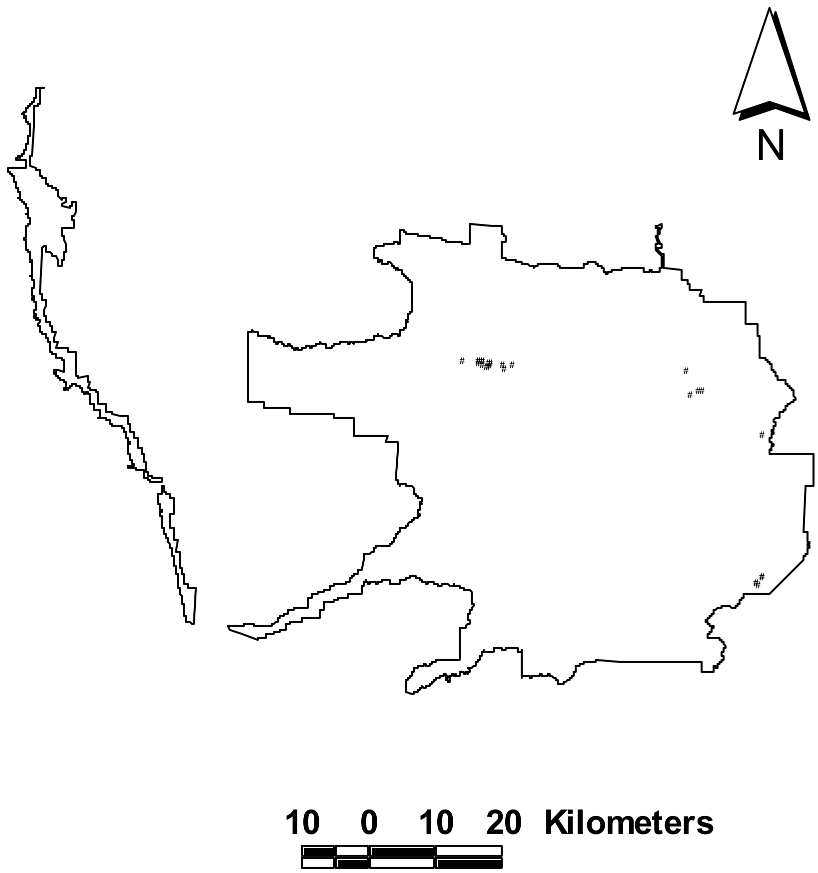


Open circles are informal surveys.
Filled circles are formal surveys.

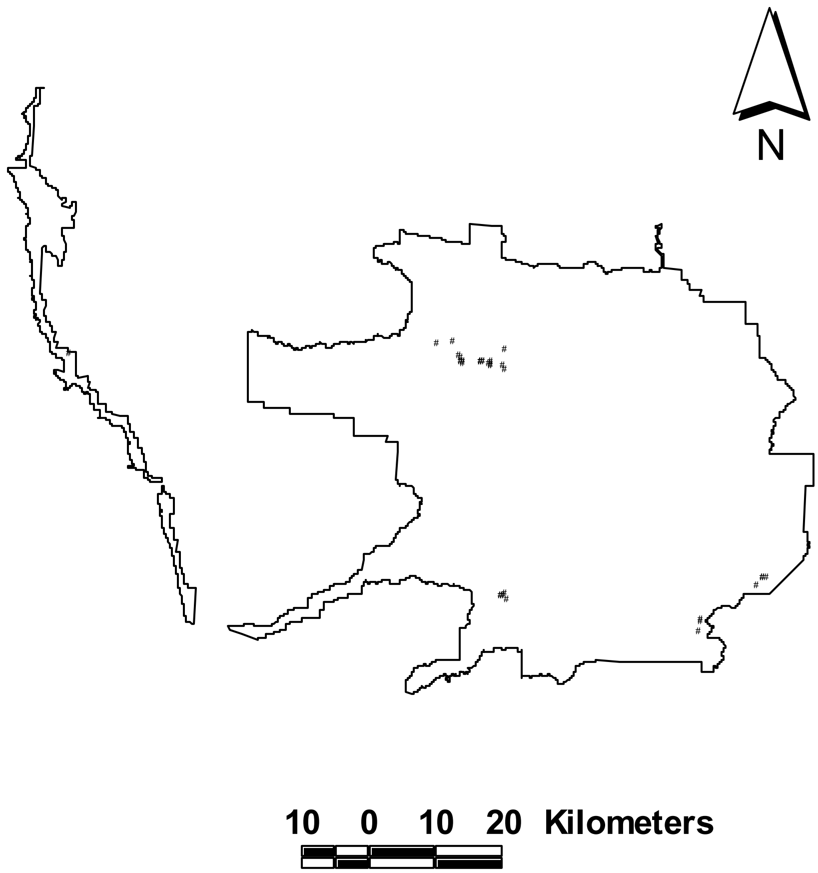
Cascades Frog



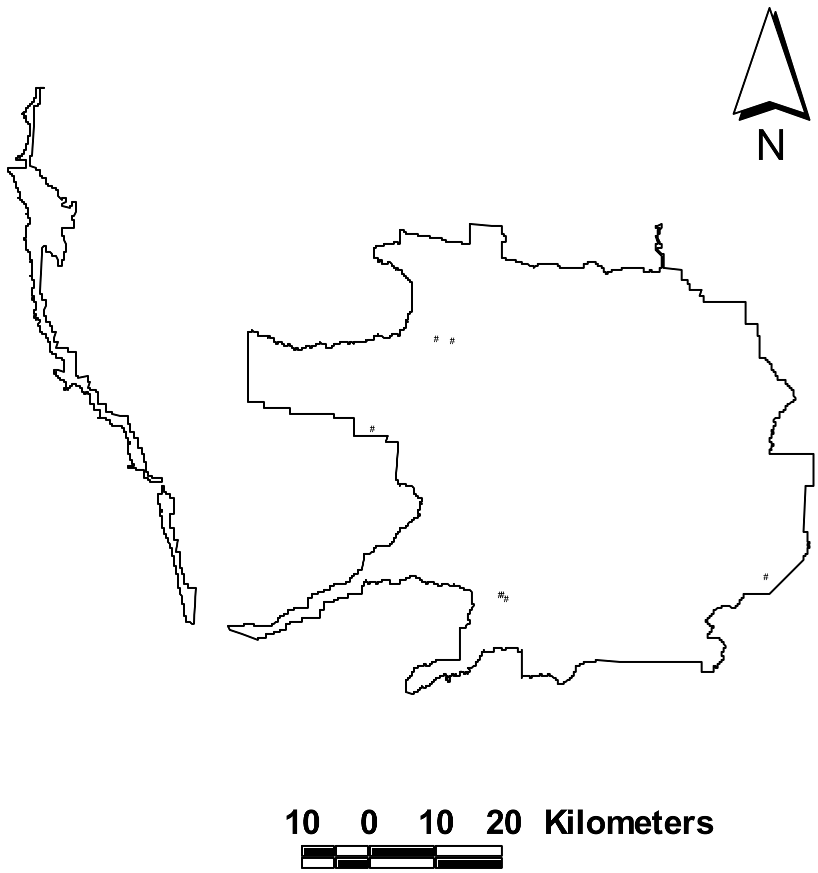
Long-Toed Salamanders



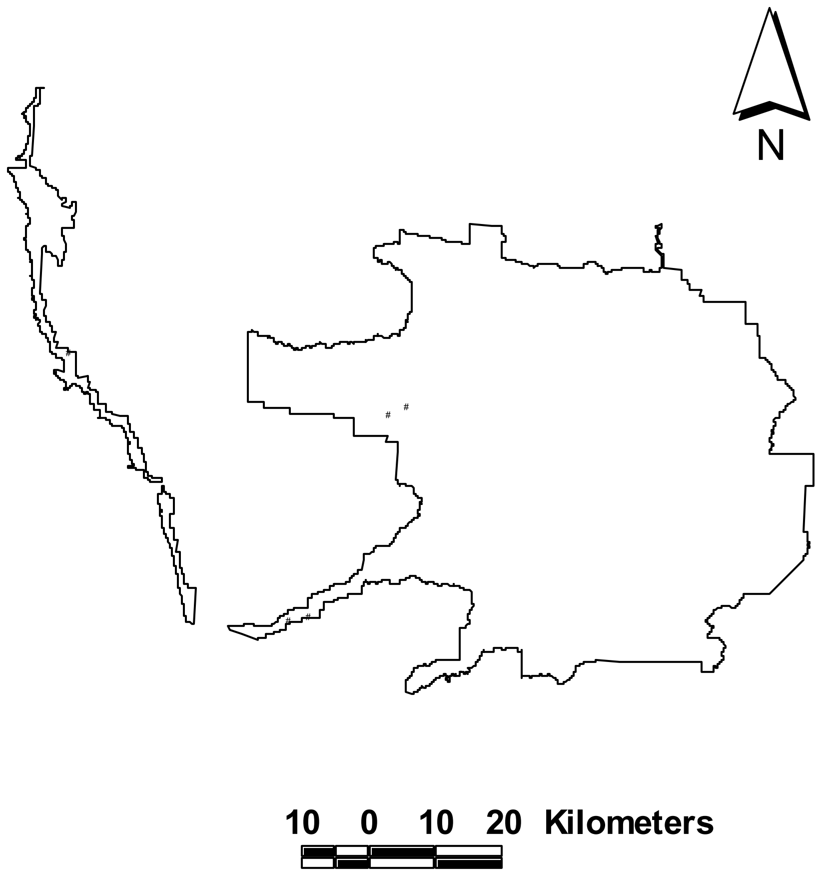
Northwestern Salamanders



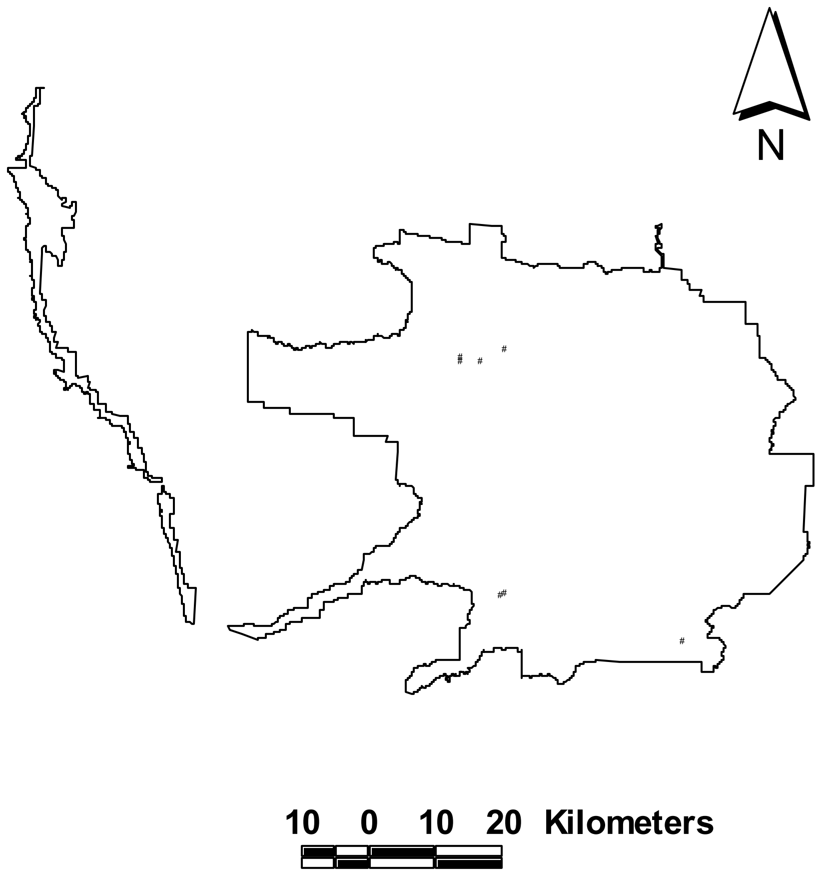
Pacific Treefrog



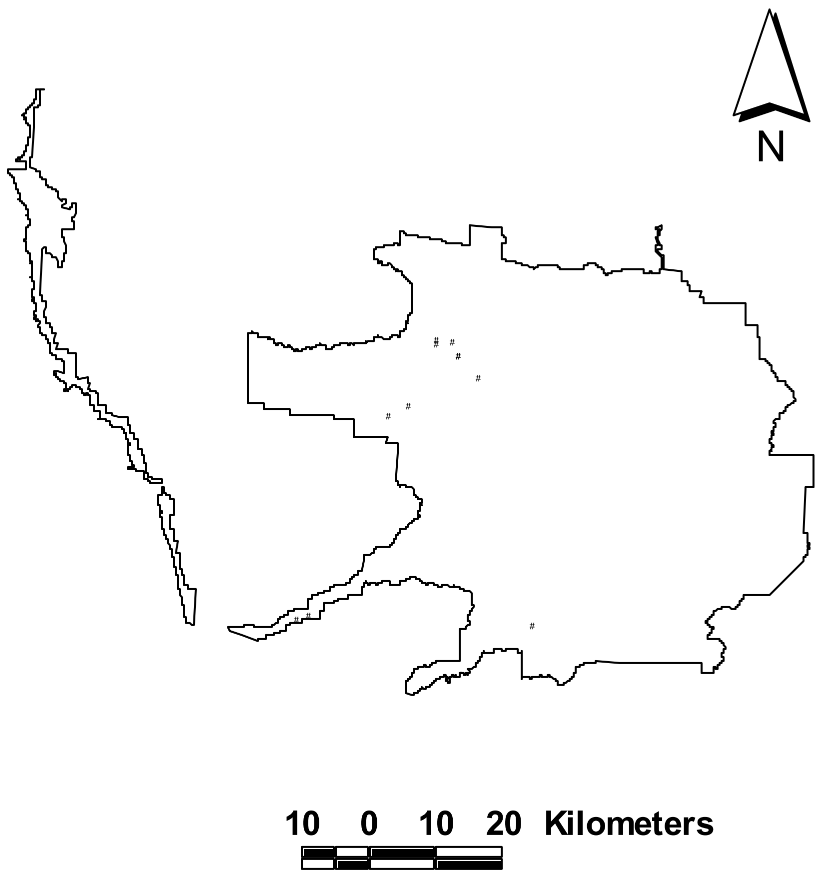
Red-Legged Frog



Rough-Skinned Newt



Western Toads



APPENDIX G. VARIABILITY OF STREAM AMPHIBIANS WITHIN STREAMS

I. Data are the mean number of animals captured per segment. N = number of segments surveyed.

			Tailed Frog			Cope's Giant Salamander			Olympic Torrent Salamander		
Stream	Date	N	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
96201	30-May-96	10	2.00	3.02	1.51	0.00	0.00	-	0.11	0.24	2.11
96202	03-Jun-96	10	2.80	2.25	0.80	0.00	0.00	-	0.12	0.37	3.16
96203	03-Jun-96	10	12.90	9.21	0.71	0.00	0.00	-	0.19	0.22	1.14
96204	05-Jun-96	10	0.20	0.42	2.11	0.00	0.00	-	0.00	0.00	-
96205	05-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96206	05-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96207	11-Jun-96	10	0.00	0.00	-	0.30	0.48	1.61	0.12	0.37	3.16
96207	13-Jun-98	10	0.00	0.00	-	0.00	0.00	-	0.61	1.35	2.22
96208	11-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.29	0.90	3.16
96209	10-Jun-96	10	0.80	0.63	0.79	0.00	0.00	-	0.00	0.00	-
96210	12-Jun-96	10	0.10	0.32	3.16	0.40	0.70	1.75	0.04	0.12	3.16
96211	13-Jun-96	10	0.20	0.63	3.16	0.90	1.29	1.43	0.09	0.13	1.45
96211	15-Jun-98	10	0.20	0.42	2.11	0.90	1.20	1.33	0.26	0.43	1.63
96212	17-Jun-96	10	0.00	0.00	-	0.20	0.63	3.16	0.26	0.56	2.15
96213	20-Jun-96	10	0.50	0.85	1.70	0.00	0.00	-	0.00	0.00	-
96214	20-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96215	16-Jun-96	10	0.00	0.00	-	0.90	0.74	0.82	0.11	0.33	3.16
96215	02-Jun-98	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96216	19-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96217	19-Jun-96	4	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96218	18-Jun-96	6	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96219	03-Jul-96	10	2.00	1.76	0.88	0.00	0.00	-	0.00	0.00	-
96220	02-Jul-96	10	2.20	1.99	0.90	0.00	0.00	-	0.00	0.00	-
96221	02-Jul-96	10	0.20	0.42	2.11	0.00	0.00	-	0.00	0.00	-
96222	09-Jul-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96223	08-Jul-96	10	0.00	0.00	-	0.00	0.00	-	0.63	0.67	1.07
96224	10-Jul-96	10	0.20	0.63	3.16	0.00	0.00	-	0.88	1.16	1.32
96225	10-Jul-96	10	0.50	0.53	1.05	0.00	0.00	-	0.58	0.77	1.32
96226	09-Jul-96	10	0.20	0.63	3.16	0.00	0.00	-	0.09	0.27	3.16
96226	25-Jun-98	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96227	18-Jul-96	10	4.50	3.06	0.68	0.00	0.00	-	0.03	0.07	2.14
96228	22-Jul-96	10	0.20	0.42	2.11	0.00	0.00	-	0.00	0.00	-
96229	15-Jul-96	10	0.00	0.00	-	0.00	0.00	-	0.98	1.88	1.93
96230	16-Jul-96	10	9.00	5.50	0.61	0.00	0.00	-	0.00	0.00	-
96231	17-Jul-96	10	4.50	3.24	0.72	0.00	0.00	-	0.03	0.08	3.16
96232	16-Jul-96	10	5.40	4.27	0.79	0.00	0.00	-	0.85	0.98	1.15
96233	01-Aug-96	10	0.10	0.32	3.16	0.10	0.32	3.16	0.39	0.57	1.47
96234	05-Aug-96	10	0.10	0.32	3.16	0.90	0.88	0.97	0.08	0.26	3.16
96235	07-Aug-96	10	0.20	0.42	2.11	0.40	0.52	1.29	0.10	0.16	1.62
96236	06-Aug-96	10	0.00	0.00	-	0.60	0.52	0.86	0.00	0.00	-
96237	06-Aug-96	10	0.70	0.95	1.36	0.20	0.42	2.11	0.19	0.40	2.14
96238	31-Jul-96	10	0.40	0.70	1.75	0.50	0.53	1.05	0.13	0.42	3.16
96239	30-Jul-96	10	1.60	3.72	2.32	1.00	0.94	0.94	0.24	0.54	2.26
96240	30-Jul-96	10	4.90	4.18	0.85	0.00	0.00	-	0.05	0.16	3.16
96241	23-Jul-96	10	0.30	0.48	1.61	0.00	0.00	-	0.00	0.00	-
96242	27-Jun-96	10	1.10	1.29	1.17	0.00	0.00	-	0.00	0.00	-
96243	23-Jul-96	10	1.50	1.90	1.27	0.00	0.00	-	0.00	0.00	-
96243	24-Jun-98	10	1.60	1.58	0.99	0.00	0.00	-	0.00	0.00	-
96244	26-Jun-96	4	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96245	25-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.44	0.68	1.54
96245	25-Jun-98	9	0.89	1.05	1.19	0.00	0.00	-	0.13	0.28	2.16
96246	24-Jul-96	10	0.00	0.00	-	0.00	0.00	-	1.36	1.04	0.77
96247	31-Aug-96	10	1.70	1.83	1.08	0.00	0.00	-	0.37	0.52	1.40
96248	30-Aug-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96249	30-Aug-96	10	1.10	1.37	1.25	0.00	0.00	-	0.21	0.46	2.18
96250	29-Aug-96	10	0.40	0.70	1.75	0.00	0.00	-	0.25	0.37	1.47
96251	27-Aug-96	10	0.00	0.00	-	0.00	0.00	-	0.62	0.37	0.59
96252	27-Aug-96	10	0.10	0.32	3.16	0.00	0.00	-	0.24	0.74	3.16
96253	28-Aug-96	10	0.60	0.84	1.41	0.00	0.00	-	0.71	0.77	1.08
96254	28-Aug-96	10	0.70	0.67	0.96	0.00	0.00	-	0.34	0.33	0.96
96255	17-Aug-96	10	2.90	1.29	0.44	0.00	0.00	-	0.70	0.47	0.66
96256	17-Aug-96	10	1.20	1.32	1.10	0.00	0.00	-	0.30	0.39	1.31
96257	16-Aug-96	10	1.50	1.72	1.14	0.00	0.00	-	0.39	0.46	1.16
96258	16-Aug-96	10	0.50	0.53	1.05	0.00	0.00	-	0.37	0.44	1.19
96259	15-Aug-96	10	2.40	1.58	0.66	0.00	0.00	-	1.81	1.15	0.64
96260	15-Aug-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96261	14-Aug-96	10	0.80	0.92	1.15	0.00	0.00	-	0.00	0.00	-
96262	14-Aug-96	2	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96263	26-Jun-96	10	0.10	0.32	3.16	0.00	0.00	-	0.13	0.40	3.16
97001	16-Jul-97	10	0.00	0.00	-	0.80	0.63	0.79	0.00	0.00	-

Stream	Date	N	Tailed Frog Mean	SD	CV	Cope's Giant Salamander Mean	SD	CV	Olympic Torrent Salamander Mean	SD	CV
97002	16-Jul-97	10	0.20	0.42	2.11	0.70	0.82	1.18	0.36	0.49	1.35
97003	17-Jul-97	10	0.00	0.00	-	0.00	0.00	-	0.15	0.32	2.11
97004	18-Jul-97	10	0.00	0.00	-	0.00	0.00	-	0.63	0.58	0.91
97005	18-Jul-97	10	1.00	1.15	1.15	0.70	0.95	1.36	0.66	0.61	0.92
97006	19-Jul-97	10	5.10	4.36	0.85	0.00	0.00	-	0.00	0.00	-
97007	19-Jul-97	10	0.00	0.00	-	0.00	0.00	-	0.59	1.29	2.20
97008	19-Jul-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97010	27-Jul-97	10	0.00	0.00	-	0.50	0.53	1.05	0.00	0.00	-
97011	27-Jul-97	10	0.40	0.70	1.75	1.30	1.49	1.15	2.44	1.33	0.55
97012	28-Jul-97	10	1.10	1.45	1.32	0.60	1.07	1.79	2.02	1.62	0.80
97013	26-Jul-97	10	5.50	4.06	0.74	0.80	0.79	0.99	0.05	0.17	3.16
97014	27-Jul-97	10	0.00	0.00	-	0.50	0.71	1.41	0.00	0.00	-
97015	26-Jul-97	10	0.00	0.00	-	0.20	0.63	3.16	0.00	0.00	-
97016	26-Jul-97	10	0.70	0.95	1.36	0.70	0.95	1.36	1.70	1.03	0.61
97017	27-Jul-97	10	1.50	1.78	1.19	0.90	1.10	1.22	0.72	0.61	0.84
97018	26-Jul-97	10	0.20	0.42	2.11	0.40	0.52	1.29	0.20	0.63	3.16
97020	28-Jul-97	10	0.00	0.00	-	0.20	0.42	2.11	0.48	0.67	1.39
97021	28-Jul-97	2	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97022	25-Jul-97	10	6.00	4.32	0.72	0.90	1.10	1.22	0.27	0.28	1.01
97023	25-Jul-97	10	1.20	1.40	1.17	1.80	1.23	0.68	0.27	0.43	1.56
97024	24-Jul-97	10	0.00	0.00	-	0.30	0.67	2.25	1.33	1.65	1.24
97025	24-Jul-97	9	0.00	0.00	-	0.11	0.33	3.00	0.08	0.25	3.00
97043	09-Aug-97	6	0.67	0.82	1.22	0.00	0.00	-	0.54	0.52	0.96
97044	09-Aug-97	5	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97045	07-Aug-97	10	0.50	1.08	2.16	0.10	0.32	3.16	0.00	0.00	-
97046	06-Aug-97	10	0.10	0.32	3.16	0.00	0.00	-	0.00	0.00	-
97047	06-Aug-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97106	06-Aug-97	10	0.00	0.00	-	1.40	1.43	1.02	0.00	0.00	-
97107	06-Aug-97	10	0.10	0.32	3.16	0.90	0.99	1.10	0.26	0.64	2.46
97108	07-Aug-97	8	0.00	0.00	-	0.00	0.00	-	0.04	0.12	2.83
97109	08-Aug-97	7	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97110	10-Jun-97	10	1.40	1.58	1.13	0.00	0.00	-	0.17	0.32	1.84
97111	11-Jun-97	10	0.00	0.00	-	0.20	0.63	3.16	0.00	0.00	-
97112	11-Jun-97	10	1.40	1.78	1.27	0.80	1.03	1.29	0.10	0.21	2.18
97113	03-May-97	10	0.00	0.00	-	0.60	0.84	1.41	0.32	0.32	1.01
97114	28-May-97	10	0.90	1.45	1.61	0.20	0.42	2.11	0.26	0.32	1.23
97115	03-Jun-97	10	0.10	0.32	3.16	0.00	0.00	-	0.10	0.20	2.14
97116	02-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97117	06-Jun-97	10	0.70	0.67	0.96	0.90	0.88	0.97	0.91	0.40	0.43
97118	05-Jun-97	8	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97119	04-Jun-97	10	0.00	0.00	-	0.90	1.73	1.92	0.05	0.15	3.16
97120	21-May-97	10	0.10	0.32	3.16	1.00	1.49	1.49	0.46	0.68	1.48
97122	22-May-97	10	0.10	0.32	3.16	0.00	0.00	-	0.00	0.00	-
97123	27-May-97	10	0.00	0.00	-	0.10	0.32	3.16	0.52	0.98	1.88
97124	27-May-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97125	29-May-97	10	0.00	0.00	-	0.50	0.97	1.94	0.05	0.11	2.12
97126	19-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97127	19-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97128	20-Jun-97	10	1.10	1.45	1.32	0.00	0.00	-	0.00	0.00	-
97129	20-Jun-97	10	0.00	0.00	-	0.10	0.32	3.16	0.00	0.00	-
97178	14-Jul-97	10	0.00	0.00	-	0.20	0.42	2.11	0.00	0.00	-
97180	15-Jul-97	9	0.11	0.33	3.00	1.11	1.54	1.38	0.00	0.00	-
97181	15-Jul-97	10	1.20	1.48	1.23	0.00	0.00	-	0.00	0.00	-
97182	02-Sep-97	10	0.00	0.00	-	0.40	0.70	1.75	0.05	0.15	3.16
97183	03-Sep-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97184	04-Sep-97	10	0.00	0.00	-	0.20	0.42	2.11	0.04	0.14	3.16
97185	14-Jul-97	10	0.10	0.32	3.16	0.10	0.32	3.16	0.02	0.05	3.16
97193	18-Jun-97	7	3.71	3.15	0.85	0.29	0.49	1.71	0.00	0.00	-
97194	17-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97195	18-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97200	18-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97221	26-Jun-97	9	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97222	26-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97223	25-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.84	1.26	1.51
97224	25-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97225	23-Jun-97	10	0.00	0.00	-	0.10	0.32	3.16	0.00	0.00	-
97226	23-Jun-97	10	1.20	1.81	1.51	0.00	0.00	-	0.06	0.12	2.17
97227	24-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.05	0.16	3.16
97228	24-Jun-97	7	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97229	24-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.15	0.47	3.16
97230	24-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97231	25-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97232	25-Jun-97	9	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97233	08-Jul-97	10	0.20	0.42	2.11	0.00	0.00	-	0.00	0.00	-
97234	07-Jul-97	10	0.60	0.97	1.61	0.10	0.32	3.16	0.00	0.00	-
97235	07-Jul-97	5	0.60	1.34	2.24	0.00	0.00	-	0.00	0.00	-
98001	20-Jul-98	10	0.90	1.20	1.33	0.00	0.00	-	0.00	0.00	-
98002	16-Jul-98	10	4.00	1.76	0.44	0.00	0.00	-	0.00	0.00	-

Stream	Date	N	Tailed Frog Mean	SD	CV	Cope's Giant Salamander Mean	SD	CV	Olympic Torrent Salamander Mean	SD	CV
98003	17-Jul-98	10	0.40	0.70	1.75	0.00	0.00	-	0.00	0.00	-
98004	18-Jul-98	10	1.10	1.60	1.45	0.00	0.00	-	0.00	0.00	-
98005	19-Jul-98	6	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98006	19-Jul-98	8	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98034	29-Jun-98	10	0.00	0.00	-	1.20	1.03	0.86	0.41	0.48	1.17
98035	30-Jun-98	10	0.00	0.00	-	0.10	0.32	3.16	0.16	0.34	2.14
98036	01-Jul-98	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98037	01-Jul-98	7	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98038	07-Jul-98	7	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98039	09-Jul-98	10	0.00	0.00	-	0.00	0.00	-	0.43	0.79	1.82
98040	08-Jul-98	10	1.20	1.14	0.95	0.00	0.00	-	0.00	0.00	-
98041	08-Jun-98	6	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98042	09-Jun-98	10	0.60	0.70	1.17	0.00	0.00	-	0.00	0.00	-
98042	04-Aug-98	30	0.57	1.04	1.84	0.00	0.00	-	0.08	0.25	3.23
98043	10-Jun-98	10	1.00	0.94	0.94	0.00	0.00	-	0.00	0.00	-
98044	10-Jun-98	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98045	11-Jun-98	10	0.80	0.79	0.99	0.00	0.00	-	0.00	0.00	-
98046	12-Jun-98	10	0.10	0.32	3.16	0.00	0.00	-	0.00	0.00	-
98047	03-Aug-98	10	0.50	0.53	1.05	0.00	0.00	-	0.00	0.00	-
98047	06-Aug-98	20	0.45	0.76	1.69	0.00	0.00	-	0.00	0.00	-
98048	05-Aug-98	30	2.00	2.42	1.21	0.00	0.00	-	0.00	0.00	-
98054	01-Jun-98	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98055	14-Jun-98	10	0.70	1.06	1.51	0.00	0.00	-	0.17	0.54	3.16
98056	04-Jun-98	10	0.40	0.70	1.75	0.00	0.00	-	0.00	0.00	-
98057	03-Jun-98	9	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98058	03-Jun-98	6	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98060	05-Aug-98	8	0.63	1.06	1.70	0.00	0.00	-	0.00	0.00	-

II. Data are the mean number of animals captured per square meter. N = the number of segments surveyed.

			Tailed Frog Tadpoles			Giant Salamander Larvae and Paedomorphs			Olympic Torrent Salamander Larvae		
Stream	Date	N	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
96201	30-May-96	10	1.43	2.35	1.65	0.00	0.00	-	0.11	0.22	2.00
96202	03-Jun-96	10	2.54	2.11	0.83	0.00	0.00	-	0.12	0.35	3.00
96203	03-Jun-96	10	3.97	1.61	0.41	0.00	0.00	-	0.19	0.21	1.08
96204	05-Jun-96	10	0.10	0.25	2.40	0.00	0.00	-	0.00	0.00	-
96205	05-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96206	05-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96207	11-Jun-96	10	0.00	0.00	-	0.25	0.41	1.65	0.12	0.35	3.00
96207	13-Jun-98	10	0.00	0.00	-	0.00	0.00	-	0.61	1.28	2.11
96208	11-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.29	0.86	3.00
96209	10-Jun-96	10	0.16	0.11	0.73	0.00	0.00	-	0.00	0.00	-
96210	12-Jun-96	10	0.04	0.12	3.00	0.29	0.60	2.06	0.04	0.11	3.00
96211	13-Jun-96	10	0.06	0.19	3.00	0.16	0.21	1.33	0.09	0.12	1.38
96211	15-Jun-98	10	0.05	0.11	2.10	0.25	0.32	1.28	0.26	0.40	1.55
96212	17-Jun-96	10	0.00	0.00	-	0.18	0.55	3.00	0.26	0.53	2.04
96213	20-Jun-96	10	0.15	0.26	1.72	0.00	0.00	-	0.00	0.00	-
96214	20-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96215	16-Jun-96	10	0.00	0.00	-	0.93	0.79	0.86	0.11	0.32	3.00
96215	02-Jun-98	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96216	19-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96217	19-Jun-96	4	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96218	18-Jun-96	6	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96219	03-Jul-96	10	1.97	1.82	0.92	0.00	0.00	-	0.00	0.00	-
96220	02-Jul-96	10	2.10	1.87	0.89	0.00	0.00	-	0.00	0.00	-
96221	02-Jul-96	10	0.12	0.24	2.04	0.00	0.00	-	0.00	0.00	-
96222	09-Jul-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96223	08-Jul-96	10	0.00	0.00	-	0.00	0.00	-	0.63	0.64	1.01
96224	10-Jul-96	10	0.10	0.29	3.00	0.00	0.00	-	0.88	1.10	1.26
96225	10-Jul-96	10	0.43	0.45	1.05	0.00	0.00	-	0.58	0.73	1.26
96226	09-Jul-96	10	0.22	0.67	3.00	0.00	0.00	-	0.09	0.26	3.00
96226	25-Jun-98	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96227	18-Jul-96	10	1.55	1.27	0.82	0.00	0.00	-	0.03	0.07	2.03
96228	22-Jul-96	10	0.06	0.11	2.00	0.00	0.00	-	0.00	0.00	-
96229	15-Jul-96	10	0.00	0.00	-	0.00	0.00	-	0.98	1.78	1.83
96230	16-Jul-96	10	4.84	3.05	0.63	0.00	0.00	-	0.00	0.00	-
96231	17-Jul-96	10	2.07	1.40	0.68	0.00	0.00	-	0.03	0.08	3.00
96232	16-Jul-96	10	4.38	4.47	1.02	0.00	0.00	-	0.85	0.93	1.10
96233	01-Aug-96	10	0.05	0.14	3.00	0.07	0.21	3.00	0.39	0.54	1.40

			Tailed Frog Tadpoles			Giant Salamander Larvae and Paedomorphs			Olympic Torrent Salamander Larvae		
Stream	Date	N	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
96234	05-Aug-96	10	0.02	0.08	3.00	0.64	0.98	1.54	0.08	0.25	3.00
96235	07-Aug-96	10	0.08	0.16	2.07	0.20	0.27	1.36	0.10	0.15	1.54
96236	06-Aug-96	10	0.00	0.00	-	0.63	0.67	1.08	0.00	0.00	-
96237	06-Aug-96	10	0.74	0.85	1.14	0.24	0.47	2.00	0.19	0.38	2.03
96238	31-Jul-96	10	0.52	0.83	1.60	0.72	0.75	1.05	0.13	0.40	3.00
96239	30-Jul-96	10	1.11	2.52	2.27	0.73	0.76	1.04	0.24	0.51	2.15
96240	30-Jul-96	10	1.66	1.58	0.95	0.00	0.00	-	0.05	0.15	3.00
96241	23-Jul-96	10	0.11	0.18	1.58	0.00	0.00	-	0.00	0.00	-
96242	27-Jun-96	10	0.35	0.38	1.09	0.00	0.00	-	0.00	0.00	-
96243	23-Jul-96	10	1.06	1.14	1.08	0.00	0.00	-	0.00	0.00	-
96243	24-Jun-98	10	1.08	0.87	0.80	0.00	0.00	-	0.00	0.00	-
96244	26-Jun-96	4	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96245	25-Jun-96	10	0.00	0.00	-	0.00	0.00	-	0.44	0.64	1.46
96245	25-Jun-98	9	0.46	0.47	1.03	0.00	0.00	-	0.13	0.26	2.04
96246	24-Jul-96	10	0.00	0.00	-	0.00	0.00	-	1.36	0.99	0.73
96247	31-Aug-96	10	0.65	0.69	1.05	0.00	0.00	-	0.37	0.49	1.33
96248	30-Aug-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96249	30-Aug-96	10	0.34	0.43	1.27	0.00	0.00	-	0.21	0.44	2.07
96250	29-Aug-96	10	0.17	0.27	1.59	0.00	0.00	-	0.25	0.35	1.40
96251	27-Aug-96	10	0.00	0.00	-	0.00	0.00	-	0.62	0.35	0.56
96252	27-Aug-96	10	0.10	0.30	3.00	0.00	0.00	-	0.24	0.71	3.00
96253	28-Aug-96	10	0.38	0.55	1.43	0.00	0.00	-	0.71	0.73	1.03
96254	28-Aug-96	10	0.31	0.29	0.95	0.00	0.00	-	0.34	0.31	0.91
96255	17-Aug-96	10	1.88	1.31	0.69	0.00	0.00	-	0.70	0.44	0.63
96256	17-Aug-96	10	0.96	1.08	1.13	0.00	0.00	-	0.30	0.37	1.24
96257	16-Aug-96	10	0.98	1.17	1.19	0.00	0.00	-	0.39	0.43	1.10
96258	16-Aug-96	10	0.26	0.31	1.22	0.00	0.00	-	0.37	0.41	1.13
96259	15-Aug-96	10	1.85	1.97	1.06	0.00	0.00	-	1.81	1.09	0.60
96260	15-Aug-96	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96261	14-Aug-96	10	0.19	0.23	1.21	0.00	0.00	-	0.00	0.00	-
96262	14-Aug-96	2	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
96263	26-Jun-96	10	0.04	0.13	3.00	0.00	0.00	-	0.13	0.38	3.00
97001	16-Jul-97	10	0.00	0.00	-	0.60	0.62	1.03	0.00	0.00	-
97002	16-Jul-97	10	0.12	0.25	2.11	0.33	0.38	1.15	0.36	0.47	1.28
97003	17-Jul-97	10	0.00	0.00	-	0.00	0.00	-	0.15	0.31	2.00
97004	18-Jul-97	10	0.00	0.00	-	0.00	0.00	-	0.63	0.55	0.87
97005	18-Jul-97	10	0.42	0.37	0.89	0.32	0.36	1.13	0.66	0.57	0.87
97006	19-Jul-97	10	1.84	1.61	0.87	0.00	0.00	-	0.00	0.00	-
97007	19-Jul-97	10	0.00	0.00	-	0.00	0.00	-	0.59	1.23	2.09
97008	19-Jul-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97010	27-Jul-97	10	0.00	0.00	-	0.56	0.56	1.01	0.00	0.00	-
97011	27-Jul-97	10	0.51	0.96	1.88	0.93	1.30	1.39	2.44	1.26	0.52
97012	28-Jul-97	10	1.11	1.61	1.45	0.45	0.83	1.87	2.02	1.54	0.76
97013	26-Jul-97	10	2.22	1.12	0.50	0.31	0.27	0.87	0.05	0.16	3.00
97014	27-Jul-97	10	0.00	0.00	-	0.79	1.23	1.55	0.00	0.00	-
97015	26-Jul-97	10	0.00	0.00	-	0.10	0.29	3.00	0.00	0.00	-
97016	26-Jul-97	10	0.41	0.48	1.17	0.31	0.40	1.31	1.70	0.98	0.57
97017	27-Jul-97	10	0.86	1.09	1.26	0.46	0.56	1.22	0.72	0.58	0.80
97018	26-Jul-97	10	0.22	0.45	2.02	0.38	0.49	1.27	0.20	0.60	3.00
97020	28-Jul-97	10	0.00	0.00	-	0.20	0.41	2.02	0.48	0.63	1.32
97021	28-Jul-97	2	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97022	25-Jul-97	10	1.97	1.62	0.82	0.22	0.24	1.08	0.27	0.26	0.96
97023	25-Jul-97	10	0.30	0.31	1.04	0.55	0.44	0.80	0.27	0.41	1.48
97024	24-Jul-97	10	0.00	0.00	-	0.32	0.67	2.07	1.33	1.57	1.17
97025	24-Jul-97	9	0.00	0.00	-	0.17	0.48	2.83	0.08	0.24	2.83
97043	09-Aug-97	6	0.40	0.43	1.08	0.00	0.00	-	0.54	0.47	0.88
97044	09-Aug-97	5	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97045	07-Aug-97	10	0.22	0.45	2.00	0.06	0.17	3.00	0.00	0.00	-
97046	06-Aug-97	10	0.03	0.10	3.00	0.00	0.00	-	0.00	0.00	-
97047	06-Aug-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97106	06-Aug-97	10	0.00	0.00	-	1.55	1.47	0.95	0.00	0.00	-
97107	06-Aug-97	10	0.05	0.14	3.00	0.72	0.78	1.10	0.26	0.61	2.33
97108	07-Aug-97	8	0.00	0.00	-	0.00	0.00	-	0.04	0.12	2.65
97109	08-Aug-97	7	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97110	10-Jun-97	10	0.39	0.43	1.10	0.00	0.00	-	0.17	0.30	1.74
97111	11-Jun-97	10	0.00	0.00	-	0.11	0.32	3.00	0.00	0.00	-
97112	11-Jun-97	10	0.51	0.55	1.09	0.40	0.59	1.49	0.10	0.20	2.07
97113	03-May-97	10	0.00	0.00	-	0.20	0.26	1.32	0.32	0.31	0.95

			Tailed Frog Tadpoles			Giant Salamander Larvae and Paedomorphs			Olympic Torrent Salamander Larvae		
Stream	Date	N	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
97114	28-May-97	10	0.47	0.65	1.39	0.09	0.18	2.10	0.26	0.30	1.16
97115	03-Jun-97	10	0.03	0.09	3.00	0.00	0.00	-	0.10	0.19	2.03
97116	02-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97117	06-Jun-97	10	0.12	0.10	0.88	0.17	0.16	0.91	0.91	0.38	0.41
97118	05-Jun-97	8	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97119	04-Jun-97	10	0.00	0.00	-	0.64	1.32	2.06	0.05	0.14	3.00
97120	21-May-97	10	0.05	0.14	3.00	0.58	0.78	1.35	0.46	0.64	1.40
97122	22-May-97	10	0.01	0.04	3.00	0.00	0.00	-	0.00	0.00	-
97123	27-May-97	10	0.00	0.00	-	0.05	0.16	3.00	0.52	0.93	1.78
97124	27-May-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97125	29-May-97	10	0.00	0.00	-	0.16	0.33	2.00	0.05	0.10	2.01
97126	19-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97127	19-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97128	20-Jun-97	10	0.29	0.39	1.33	0.00	0.00	-	0.00	0.00	-
97129	20-Jun-97	10	0.00	0.00	-	0.04	0.12	3.00	0.00	0.00	-
97178	14-Jul-97	10	0.00	0.00	-	0.10	0.20	2.06	0.00	0.00	-
97180	15-Jul-97	9	0.03	0.08	2.83	0.33	0.44	1.35	0.00	0.00	-
97181	15-Jul-97	10	0.19	0.21	1.13	0.00	0.00	-	0.00	0.00	-
97182	02-Sep-97	10	0.00	0.00	-	0.14	0.27	1.84	0.05	0.14	3.00
97183	03-Sep-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97184	04-Sep-97	10	0.00	0.00	-	0.09	0.20	2.18	0.04	0.13	3.00
97185	14-Jul-97	10	0.03	0.09	3.00	0.02	0.05	3.00	0.02	0.05	3.00
97193	18-Jun-97	7	1.56	1.84	1.18	0.06	0.10	1.60	0.00	0.00	-
97194	17-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97195	18-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97200	18-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97221	26-Jun-97	9	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97222	26-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97223	25-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.84	1.20	1.43
97224	25-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97225	23-Jun-97	10	0.00	0.00	-	0.11	0.32	3.00	0.00	0.00	-
97226	23-Jun-97	10	0.32	0.42	1.31	0.00	0.00	-	0.06	0.11	2.06
97227	24-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.05	0.15	3.00
97228	24-Jun-97	7	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97229	24-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.15	0.44	3.00
97230	24-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97231	25-Jun-97	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97232	25-Jun-97	9	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
97233	08-Jul-97	10	0.06	0.13	2.00	0.00	0.00	-	0.00	0.00	-
97234	07-Jul-97	10	0.11	0.17	1.56	0.03	0.09	3.00	0.00	0.00	-
97235	07-Jul-97	5	0.09	0.18	2.00	0.00	0.00	-	0.00	0.00	-
98001	20-Jul-98	10	0.72	1.04	1.43	0.00	0.00	-	0.00	0.00	-
98002	16-Jul-98	10	1.46	0.75	0.52	0.00	0.00	-	0.00	0.00	-
98003	17-Jul-98	10	0.22	0.37	1.70	0.00	0.00	-	0.00	0.00	-
98004	18-Jul-98	10	0.95	1.43	1.51	0.00	0.00	-	0.00	0.00	-
98005	19-Jul-98	6	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98006	19-Jul-98	8	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98034	29-Jun-98	10	0.00	0.00	-	0.81	0.72	0.89	0.41	0.46	1.11
98035	30-Jun-98	10	0.00	0.00	-	0.12	0.38	3.00	0.16	0.32	2.03
98036	01-Jul-98	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98037	01-Jul-98	7	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98038	07-Jul-98	7	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98039	09-Jul-98	10	0.00	0.00	-	0.00	0.00	-	0.43	0.75	1.73
98040	08-Jul-98	10	1.32	1.18	0.89	0.00	0.00	-	0.00	0.00	-
98041	08-Jun-98	6	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98042	09-Jun-98	10	0.26	0.30	1.12	0.00	0.00	-	0.00	0.00	-
98042	04-Aug-98	30	0.32	0.53	1.63	0.00	0.00	-	0.08	0.25	3.18
98043	10-Jun-98	10	0.50	0.45	0.91	0.00	0.00	-	0.00	0.00	-
98044	10-Jun-98	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98045	11-Jun-98	10	0.47	0.41	0.88	0.00	0.00	-	0.00	0.00	-
98046	12-Jun-98	10	0.06	0.17	3.00	0.00	0.00	-	0.00	0.00	-
98047	03-Aug-98	10	0.22	0.24	1.10	0.00	0.00	-	0.00	0.00	-
98047	06-Aug-98	20	0.21	0.36	1.75	0.00	0.00	-	0.00	0.00	-
98048	05-Aug-98	30	0.88	1.22	1.38	0.00	0.00	-	0.00	0.00	-
98054	01-Jun-98	10	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98055	14-Jun-98	10	0.27	0.37	1.37	0.00	0.00	-	0.17	0.51	3.00
98056	04-Jun-98	10	0.17	0.27	1.56	0.00	0.00	-	0.00	0.00	-
98057	03-Jun-98	9	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-

			Tailed Frog Tadpoles			Giant Salamander Larvae and Paedomorphs			Olympic Torrent Salamander Larvae		
Stream	Date	N	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
98058	03-Jun-98	6	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
98060	05-Aug-98	8	0.39	0.59	1.54	0.00	0.00	-	0.00	0.00	-

APPENDIX I: SPOTTED FROG CAPTURE HISTORIES

Capture histories for spotted frogs at Dagger Lake. A ‘1’ indicates that the frog with the indicated mark was captured on the date appearing at the column head.

Mark	08/23/1997	08/24/1997	08/25/1997
1	1		
2	1	1	
3	1		1
4	1		
5	1		
6	1		
7	1		
8	1		1
9	1	1	1
10	1		
11	1		
12	1		
13	1		
14	1		
15	1		1
16	1		
17	1		
18	1		
19	1		
20	1		
21	1		
22	1	1	
23	1		
24	1		
25	1		1
26	1		
27	1		
28	1	1	1
29	1		
30	1	1	
31	1		
32	1		
33	1		
34	1		
35	1		
36	1		
37	1		
38	1		
39	1		
40	1		
41	1		
42	1		
43	1		1
44	1	1	
45	1		
46	1		
47	1		
48	1		
49	1		
50	1	1	
51	1		
52	1		
53	1		
54	1		
55	1		
56	1		1
57	1		
58	1		
59	1		
60	1		
61	1		
62	1		
63	1		
64	1		
65	1		
66	1		
67	1		
68	1	1	
69	1		
70	1		
71	1	1	1
72	1		1
73	1		
74	1		
75	1		
76	1		
77	1		
78	1		
79	1		1
80	1		
81	1	1	
82	1		1
83	1		
84	1		
85	1		
86	1		1
87		1	
88		1	
89		1	
90		1	1
91		1	
92		1	
93		1	1
94		1	
95		1	
96		1	
97	1		
98	1		
99		1	
101	1		
102		1	
103		1	
104		1	
105		1	
106		1	
107		1	
108		1	
109		1	1
112		1	
113		1	
115		1	
117		1	
118		1	
122		1	
123		1	1
124		1	
125		1	
126		1	
127		1	
128			1
129			1
132			1
134			1
135			1
136			1
137			1
138			1
139			1
142			1
143			1
144			1
145			1

Mark	08/23/1997	08/24/1997	08/25/1997
146			1
147			1
148			1
149			1
152			1
153			1
154			1
155			1
156			1

APPENDIX J: UPDATE ON POND AND STREAM SURVEYS FUNDED BY THE I&M PROGRAM

In 1999, under the I&M project, we conducted additional surveys of amphibian populations to supplement those already completed under the NRPP project. One objective in 1999 was to survey the gravel bar pools of the Quinalt, Queets, and Skokomish rivers for the presence of breeding populations of the western toad (*Bufo boreas*). Our previous surveys of high elevation ponds and lakes revealed few toad populations. A second objective of the 1999 surveys was to complete pond amphibian surveys throughout the park to gain wider coverage. A third 1999 objective was to survey streams and seeps in the Duckabush, a drainage that had not been surveyed before, and continue stream monitoring in the Elwha. These data, together with data from previous years, provides baseline information on the distribution of amphibians in the park.

Western Toad Surveys

Western toad populations were identified in gravel bar ponds of the Quinalt and the Queets rivers (Table 18). A total of 75 ponds were surveyed on gravel bars on the southwest and southeast sides of the park. The Queets drainage also had Pacific tree frogs (*Hyla regilla*) and red-legged frogs (*Rana aurora*) in gravel bar pools.

Pond Amphibian Surveys

Pond and lake surveys in 1999 covered 10 drainages. Amphibians were found in each drainage (Table 19). Eighty surveys were conducted at 77 ponds (Table 21).

Stream Amphibian Surveys

The Duckabush drainage on the central-

Table 18. Number of western toad populations found in gravel bar ponds.

STREAM	# OF GRAVEL BARS	# OF PONDS	TOAD POPULATIONS
Quinalt	2	13	3
Queets	5	48	17
Skokomish	7	14	0
Total	14	75	20

Table 19. Number of amphibian populations detected in each drainage during 1999 pond surveys. Number of breeding populations is in parentheses.

DRAINAGE (# of Surveys)	N	AMGR	AMMA	BUBO	HYRE	RAAU	RACA	TAGR
Grey wolf	18	0	10(9)	0	0	0	14(13)	0
Hoh	5	3(3)	0	0	3(3)	5(5)	0	1(0)
Lyre	6	3(3)	1(1)	1(0)	3(1)	1(0)	3(2)	3(2)
Morse Creek	3	0	1(1)	1(1)	1(0)	0	3(1)	2(0)
North Fork Quinalt	1	1(1)	0	1(1)	1(1)	1(1)	0	1(0)
Ozette	3	2(2)	0	1(1)	1(1)	2(2)	1(0)	0
Quinalt	4	2(2)	0	0	0	0	2(1)	0
Skokomish	29	6(6)	10(10)	0	0	0	18(12)	0
Solduc	4	2(2)	0	0	1(1)	1(0)	0	0
Wynoochee	7	2(2)	4(4)	0	0	0	7(6)	0
Total # of Populations	80	21(21)	26(25)	4(3)	10(7)	10(8)	48(35)	7(2)

AMGR = Ambystoma gracile; AMMA = Ambystoma macrodactylum; BUBO = Bufo boreas; HYRE = Hyla regilla; RAAU = Rana aurora; RACA = Rana cascadae; TAGR = Taricha granulosa

Table 20. Location of 1999 stream/seep surveys and number of individuals found.

SITE #	DRAINAGE	CLASS	UTM_N	UTM_E	Elev(m)	ASTR	DICO	RHOL	PLVE
99001	Duckabush	Stream	5282140	489660	1300	0	0	0	0
99002	Duckabush	Stream	5282120	489240	1350	13	0	0	0
99003	Duckabush	Stream	5282160	489060	1440	2	0	0	0
99004	Duckabush	Stream	5282000	488700	1440	0	0	0	0
99005	Duckabush	Stream	5281860	488660	1350	2	0	0	0
99102	Duckabush	Seep	5280650	486220	440	0	0	0	0
99104	Duckabush	Seep	5280600	486040	440	0	0	0	0
99114	Duckabush	Seep	5280020	484700	1520	0	0	0	0
99116	Duckabush	Seep	5279680	483980	1760	1	0	0	0
99118	Duckabush	Seep	5279710	483700	1800	1	0	0	0
99119	Duckabush	Seep	5279710	483600	1800	0	0	5	0
96243	Elwha (96)	Stream	5317920	456240	400	15	0	0	0
96243	Elwha (98)	Stream	5317920	456240	400	16	0	0	0
96243	Elwha (99)	Stream	5317920	456240	400	47	0	1	1

east side of ONP, was surveyed in 1999 for the first time. Sampling methods followed the same protocol as described for NRPP stream surveys. Out of 11 sites in the Duckabush, five were found with tailed frogs (*Ascaphus truei*) present and one had Olympic torrent salamanders (*Rhyacotriton olympicus*) present (Table 20). No Cope's giant salamanders (*Dicamptodon copei*) were found in the Duckabush drainage. One stream in the Elwha drainage, Mule Creek, has been surveyed in 1996, 1998, and 1999. Tailed frog larvae were found in abundance all three years. Plus, in the 1999 survey, one adult western redback salamander (*Plethodon vehiculum*) and one larval Olympic torrent salamander were recorded (Table 20).

Conclusion

The surveys indicate that, while western toads are rare at high elevation ponds, they are more common along rivers in the southwest area of the Park. It is not known how common the western toads were historically in ONP or whether their rarity at high elevation ponds represents a decline. This is a potential concern because western toads appear to be declining elsewhere and are known to breed at high elevations in other regions of the USA. Their use of gravel bar pools has not been previously described, but appears to be an important habitat in ONP and further research is recommended.

In high elevation ponds the Cascade frog is quite abundant. This is consistent with results from the PRIMENet study conducted during the same time as well as NRPP studies from previous years. Surveys in 1999 support the previous years' data in that Cascade frogs were less likely to occur when exotic fish (brook trout) were present and long-toed salamanders never co-occurred with exotic fish. Ponds located in the low elevation, coastal strip of ONP, had red-legged frogs, Pacific tree frogs, western toads, and northwestern salamanders present during surveys.

The Duckabush drainage appears to have abundant populations of tailed frogs but Cope's giant salamander was not detected. Surveys from previous years failed to find Cope's giant salamander from the Lyre River drainage, on the NW side of the park, all the way around to the Duckabush drainage on the SE side. However, there were limited numbers of surveys conducted in the Duckabush and Morse drainages (5 and 6 surveys respectively). The Elwha drainage had 28 stream sites surveyed. The habitat in these drainages appear suitable for Cope's salamanders. Hydrology and potential pollution from the Seattle area should be investigated as possible causes for the absence of Cope's salamanders.

Table 21. I&M pond amphibian surveys (1999). Location and species found.

DRAINAGE	SITE ID	UTM EAST	UTM NORTH	AMGR	AMMA	BUBO	HYRE	RAAU	RACA	TAGR
LYRE	EAGLE1	432667	5321867	2	2	0	1	0	1, 2	1, 2
LYRE	EAGLE2	432805	5322017	1,2	0	1	1, 2	0	1, 2	1
LYRE	EAGLE3	432841	5322183	2	0	0	1	1	1	2
OZETTE	ERICSON BAY POND	376427	5330414	2	0	2	2	2	0	0
GREY WOLF	GL110	473242	5304827	0	1, 2	0	0	0	1, 2	0
GREY WOLF	GL111	473589	5304634	0	0	0	0	0	1, 2	0
GREY WOLF	GL111A	473581	5304603	0	0	0	0	0	1	0
GREY WOLF	GL113	473890	5303396	0	1	0	0	0	1,2	0
GREY WOLF	GL113A	473856	5303401	0	2	0	0	0	1,2	0
GREY WOLF	GL117	474309	5302820	0	2	0	0	0	1, 2	0
GREY WOLF	GL120	473280	5302593	0	2	0	0	0	1, 2	0
GREY WOLF	GL120A	473183	5302517	0	1, 2	0	0	0	1, 2	0
GREY WOLF	GL121	473081	5302521	0	2	0	0	0	1, 2	0
GREY WOLF	GL121A	473089	5302530	0	2	0	0	0	1, 2	0
GREY WOLF	GL121B	473088	5302468	0	0	0	0	0	0	0
GREY WOLF	GL122	473844	5302052	0	0	0	0	0	0	0
GREY WOLF	GL122A	473805	5302023	0	0	0	0	0	0	0
GREY WOLF	GL123	473109	5302014	0	0	0	0	0	1, 2	0
GREY WOLF	GL124	472943	5302245	0	0	0	0	0	0	0
GREY WOLF	GL125	473189	5302094	0	2	0	0	0	1, 2	0
GREY WOLF	GL126	473118	5302375	0	0	0	0	0	1, 2	0
GREY WOLF	GL127	473745	5302852	0	2	0	0	0	1, 2	0
HOH	HOH-1	423370	5296581	2	0	0	1, 2	1, 2	0	1
HOH	HOH-2	430064	5301054	0	0	0	2	2	0	0
HOH	HOH-3	430015	5301018	0	0	0	2	1, 2	0	0
HOH	HOH-3A	430077	5301036	2	0	0	0	2	0	0
HOH	HOH-4	430100	5301060	2	0	0	0	2	0	0
MORSE CRK	LAKE ANGELES	467733	5316919	0	0	0	0	0	1	1
MORSE CRK	LAKE ANGELES-A			0	2	0	1	0	1, 2	1
NF QUINALT	NFQ-IRELY	449414	5268131	2	0	2	2	1, 2	0	1
MORSE CRK	PJ LAKE	469083	5310230	0	0	2	0	0	1	0
OZETTE	SEAFIELD LAKE	374500	5338900	2	0	0	0	2	0	0
SOLDUC	SOLDUC1	428597	5324925	2	0	0	2	0	0	0

DRAINAGE	SITE ID	UTM EAST	UTM NORTH	AMGR	AMMA	BUBO	HYRE	RAAU	RACA	TAGR
SOLDUC	SOLDUC2	434675	5313353	2	0	0	0	1	0	0
QUINALT	SR800	460338	5265358	0	0	0	0	0	2	0
QUINALT	SR801	460339	5265355	0	0	0	0	0	0	0
WYNOOCHEE	SR802	458750	5264880	1, 2	1, 2	0	0	0	1, 2	0
WYNOOCHEE	SR802A	458724	5264832	0	0	0	0	0	1, 2	0
WYNOOCHEE	SR802B	458791	5264861	2	0	0	0	0	1, 2	0
WYNOOCHEE	SR803	458784	5264913	0	2	0	0	0	1, 2	0
WYNOOCHEE	SR803A	458780	5264929	0	2	0	0	0	1	0
WYNOOCHEE	SR804	458811	5264916	0	1, 2	0	0	0	1, 2	0
WYNOOCHEE	SR804A	458809	5264926	0	0	0	0	0	1, 2	0
QUINALT	SR805	461586	5264651	2	0	0	0	0	0	0
SKOKOMISH	SR806	463486	5265772	2	1, 2	0	0	0	1	0
SKOKOMISH	SR806A	463422	5265751	0	0	0	0	0	0	0
SKOKOMISH	SR806B	463420	5265759	0	0	0	0	0	2	0
SKOKOMISH	SR806C	463414	5265760	0	0	0	0	0	0	0
SKOKOMISH	SR806D	463412	5265762	0	2	0	0	0	1	0
SKOKOMISH	SR806E	463414	5265765	0	0	0	0	0	1, 2	0
SKOKOMISH	SR806F	463403	5265779	0	2	0	0	0	0	0
SKOKOMISH	SR806G	463418	5265780	0	0	0	0	0	0	0
SKOKOMISH	SR807	463563	5265673	2	2	0	0	0	0	0
SKOKOMISH	SR808	463375	5265792	0	1, 2	0	0	0	1, 2	0
SKOKOMISH	SR809	463315	5265814	2	2	0	0	0	1, 2	0
SKOKOMISH	SR809A	463329	5265815	0	0	0	0	0	0	0
SKOKOMISH	SR809B	463326	5265819	0	0	0	0	0	0	0
SKOKOMISH	SR809C	463328	5265821	0	0	0	0	0	1	0
SKOKOMISH	SR810	463214	5265732	2	0	0	0	0	1, 2	0
QUINALT	SR812	462526	5266575	2	0	0	0	0	1	0
SKOKOMISH	SR813	463956	5265969	0	0	0	0	0	0	0
SKOKOMISH	SR814	464205	5266160	0	0	0	0	0	0	0
SKOKOMISH	SR815	464509	5266174	0	0	0	0	0	0	0
SKOKOMISH	SR816	464659	5266084	1, 2	0	0	0	0	1, 2	0
SKOKOMISH	SR817	465182	5266315	0	0	0	0	0	1	0
SKOKOMISH	SR818	463112	5265646	2	2	0	0	0	1, 2	0
SKOKOMISH	SR818A	463126	5265641	0	0	0	0	0	0	0
SKOKOMISH	SR818B	463106	5265644	0	2	0	0	0	1	0

DRAINAGE	SITE ID	UTM EAST	UTM NORTH	AMGR	AMMA	BUBO	HYRE	RAAU	RACA	TAGR
SKOKOMISH	SR819	463028	5265740	0	0	0	0	0	1, 2	0
SKOKOMISH	SR820	462831	5265633	0	2	0	0	0	1, 2	0
SKOKOMISH	SR821	462836	5265628	0	2	0	0	0	1, 2	0
SKOKOMISH	SR822	462833	5265621	0	0	0	0	0	1, 2	0
SKOKOMISH	SR823	462833	5265616	0	0	0	0	0	1, 2	0
SKOKOMISH	SR824	462810	5265624	0	0	0	0	0	1	0
OZETTE	WILLOUGHBY LAKE	374964	5343788	0	0	0	0	0	1	0

0=not present; 1=adult or juvenile; 2=egg or larvae